Popular Astronomy.

Vol. XV, No. 10. DECEMBER, 1907. Whole No. 150

AN ASTRONOMICAL THEORY OF THE MOLECULE AND AN ELECTRONIC THEORY OF MATTER. I.

Solar and Terrestrial Physics Viewed in the Light Thereof.

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For Popular Astronomy.

Prefatory Statements.

In the year 1891 while engaged in the study of "radiation", from a theoretical standpoint with a view of obtaining some very desirable and important practical results my attention was, quite casually, attracted to a simple phenomenon exhibited by an incandescent electric lamp that had been in operation during a more or less prolonged period.

This phenomenon, which is of so common occurrence in the case of lamps of this kind and type, and apparently so trivial in nature that it would ordinarily pass unnoticed, is the slight blackening, or discoloration, of the interior surface of the glass bulb inclosing the carbon filament whence the light of this kind of lamp is radiated,—the source whence the sooty matter, so deposited, is derived, being obviously, the carbon of which the filament is composed.

A non-scientific observer if his attention were at all attracted to this phenomenon would probably attribute it to the same cause that effects the blackening, or "smoking", of the interior surface of the glass chimney of an ordinary oil-lamp, viz., to the deposition of sooty matter, or the finely divided particles of amorphous carbon, resulting from the imperfect combination due either to deficiency of oxygen or to the inability of that gas to properly reach and chemically attack the carbonaceous matter of the lampwick, with such energy as to effect a thorough transformation of said matter into the invisible gas "carbon dioxide" or, in other words, to effect a complete combustion. But, when the fact is considered that, from the interior of the bulb inclosing the filament, the air has been exhausted to nearly the minimum possible degree of pressure (the pressure of the residual gases within the bulb being as low as the one-millionth part of an "atmosphere" as the normal atmospheric pressure of

approximately 14¾ pounds per square inch is called) mainly for the purpose of preventing the speedy destruction of the delicate carbon filament, by complete and instantaneous burning which would occur if the filament, when highly heated by the electric current coursing through it, were exposed to air, at ordinary pressures, with its abundant supply of the active agent in the process of combustion-oxygen,— it becomes very evident that, whatever may be the cause of the phenomenon, it can not be due to the wafting of unburned corpuscles of carbon from the heated filament by convection currents circulating in the residual gases within the bulb, and the deposition of these carbon particles upon the interior surface of that inclosing vessel, as smoke from an exposed fire is borne on the "wings of the wind" to deposit its sooty matter on the surface of surrounding objects, because in the first place the quantity of oxygen remaining in the bulb after "exhaustion" of the air originally filling that vessel bears, of course, the same proportion with respect to the other principal gaseous component of atmospheric air—nitrogen—as it does in the case of "free air," this proportion, by weight being very approximately 23 of oxygen and 77 of nitrogen. With sufficient accuracy oxygen may be regarded as comprising one-fourth of the weight of free air and also of the residual gases within the bulb, and since the latter are reduced to about the millionth part of an "atmosphere", it follows that the weight of oxygen in the bulb, when ready for use is only the $\frac{1}{4{,}000{,}000}$ of the weight of a volume of "free air", equal to the volume inclosed by the walls of the bulb, and as this volume is small and the weight of air comprised within it correspondingly light it follows that the weight of oxygen in the residual air within the bulb, must be inappreciable in fact a rough calculation shows its weight to be only about the one-millionth part of a grain. Moreover, this minute portion of oxygen remaining in the inclosing vessel, immediately after the process of "exhaustion", must, when the lamp is first put in operation, be greatly reduced, or even wholly eliminated, by chemical combination with a correspondingly minute portion of the carbon of the filament the product being one or both of the oxides of carbon, viz, carbon dioxide or carbonic acid gas, and carbon moreoxide both of which are invisible gases, which cannot be factors in the causation of the phenomenon under discussion in this immediate connection. Secondly in such an attenuated atmos-

phere as that within the bulb, when the lamp is ready for use, there cannot well be any convection currents comparable to those circulating in open air, and capable of transporting carbon corpuscles from the filament to the interior surface of the bulb, as the wind carries smoke; the hypothesis above stated must therefore be rejected.

Another hypothetical cause that may suggest itself to a student of "analytical mechanics" is that each comminuted particle or corpuscle, of unconsumed carbon thus deposited upon the interior surface of the bulb, may have been impelled from the surface of the filament, and projected against that of the glass, by an impulsive force the same as—or analogous to—that which actuates a projectile fired from a gun; but this concept, while quite plausible, is not tenable because there is, absolutely, no foundation of fact upon which the existence of such an impulsive force can be based. We know that in the case of the projectile aforesaid, the force that overcomes the inertia of the projectile and speeds it along its "trajectory", is one of "pressure" suddenly developed on one side of the projectile by the generation and expansion of gases consequent upon the explosion or instantaneous combustion of the compound forming the "charge" confined within the bore of the gun, but in the case of the carbon corpuscles seemingly impelled as projectiles, we have no evidence whatever to indicate the existence of matter or forces within the filament, competent to cause effects the same as or similar to those known to be factors in the case of the Sun.

A physicist viewing the subject from his special scientific standpoint would probably assign as a cause of said phenomenon the physical process known as "diffusion" or that by which the molecules of two or more different gases in perfect equilibrium with each other as to pressure gradually intermingle throughout extensive volumes, and also that whereby finely divided invisible particles or corpuscles of an aromatic substance are slowly transported through very considerable distances in perfectly quiescent air which becomes permeated with the specific odor of the substance aforesaid; the "conduction" of heat may also be regarded as a process of "diffusion" which is extremely slow in gaseous matter, all of which is of very low thermal conductivity.

The physicist might also regard the phenomenon exhibited by the electric lamp aforesaid as the result of what the late Professor J. Clerk Maxwell termed the "pressure of light"

which is exemplified by Crookes' interesting scientific toy known as the "light mill" which consists simply of small vanes or disks (having certain sides blackened) arranged upon an axis around which they can freely revolve, these vanes being inclosed in a glass bulb whence the air is exhausted to a very low pressure in a manner similar to that used in the case of the incandescent electric lamp, which vanes, when direct sunlight is allowed to fall upon them, revolve around their axis actuated by an unbalanced pressure due to the impringing light.

Finally a student of electrical science, in its fundamental aspects, if asked for an explanation of the phenomenon in question would probably say that it is caused by a difference of "electrical potential" between the filament conveying the current of electricity whereby the lamp is actuated and the internal surface of the glass bulb, through a process quite analogous to that by which the "ions" in an electrolytic solution are deposited on the "electrodes", or as the molecules of hydrogen, originally in chemical combination with oxygen in the water of a battery solution, are dissociated from the latter by a chemical reaction productive of an electric current, and apparently transported to and deposited upon the positive pole of carbon, copper or platinum in each cell of a galvanic battery; or finally to use a more modern and perhaps more appropriate analogy, to action similar to that by which the "negative corpuscles" or "electrons" (as they have been called of late) in the case of electrical discharges in rarefied gases, are projected against the cathode in a Crookes, Geissler or similar tube. The first and second of the four hypotheses presented in the few preceding paragraphs, having been rejected as untenable for reasons set forth, we are restricted to a consideration of the third and fourth, or to that one which attributes the cause of the phenomenon in question to either the physical process called "diffusion", or to the "pressure of light", and to that which regards the phenomenon as being caused by difference of "electrical potential", as manifested by its several modes of operation.

It is well-known by students of this subject that the process called "diffusion" is a physical action that operates mainly through the medium of gaseous and liquid matter although in a sense we may regard what is called the "conduction of heat" as a diffusion not of *matter* but of *motion*, and that the sphere of action in all cases includes not only

what has been called "gross matter," gases, liquids and solids, but also that superlatively tenuous, well-nigh imponderable, omnipresent, all-prevading,—hypothetical fluid which acts as the medium by, and through which, "radiance" of all kinds is propagated, or transmitted, and which fills all known space extending outward from the Earth to at least the distance through which it bears to our eyes, at the rate of 186,340 miles per second, the light of the most distant star visible through the most powerful telescope, which distance if we may judge from known stellar parallax, is certainly not less and probably much greater than two million times the mean distance of the Sun from the Earth, or roughly in round numbers 200,000,000,000,000 miles.

This wonderful matter, from its function as the "bearer of light", has been called the "luminiferous ether", but it is also the medium by and through which other radiant forces such as heat and electricity are borne with almost inconceivably great—yet measurable—velocity which may be regarded as of the same order of magnitude as the "velocity of light" which has been very accurately determined by several different experimental methods, the value according to Newcomb being 186,340 miles per second.

The so-called "gross matter" included within the bulb of an incandescent electric lamp is, obviously, of the same general composition as that of the atmospheric air outside this inclosing vessel, it being simply such air greatly reduced in density and pressure by the process of "exhaustion", and is therefore consisting principally of nitrogen and oxygen gases, together with a modicum of aqueous-vapor, carbon dioxide and traces of argon and the several other chemically inert gases of quite recent discovery, while the transmission of light and also of heat from the carbon filament of the lamp in operation indicates obviously the presence of the ether either in a discrete state, separate and distinct from the gross matter mentioned or else in some condition of more or less intimate connection therewith, or relationship thereto.

The several physical processes and forces suggested in preceding paragraphs as being those operative in the causation of the special phenomenon displayed in the case of the electric lamp as stated in the initial paragraphs of this paper, acting as they do through the medium of the gross matter and the ether included within the glass bulb of the lamp, it becomes necessary, if we would obtain a clear knowledge of the exact nature of the processes and forces to have an intimate knowl-

edge of the fundamental constitution of these several forms of matter, as to their ultimate particles, the atoms and the molecules composed thereof, and of the forces acting upon these atoms and molecules, and since we know the several kinds of matter, gaseous and other, included within the bulb as we know all forms of matter, only by certain specific chemical, mechanical or other physical properties possessed and exhibited by them, the proper scientific mode of procedure in order to obtain a more intimate knowledge of the exact or absolute nature of such matter and forces is to formulate some working hypothesis concerning the question, to submit the theoretical results indeed therefrom to a rigorous comparison with those of observation or experiment and then to judge from the concordance, or the discordance, between the theoretical deductions and the facts disclosed by actual observation or experiment as to the truth, or falsity, of the postulates of the hypothesis and as to acceptance of the latter as a veritable theory or its rejection as a fallacy. The question is often asked even by generally well-informed persons concerning any established theory of physics and particularly any theory dealing with the constitution of matter and the physical forces acting upon and through it and especially with the invisible intangible ultimate particles called atoms and their compounds the molecules. How do you know that this theory is true? To which the answer must be given, that according to a fundamental and logical canon of science if such a theory fully and satisfactorily accounts for or explains *all* the physical phenomena within its scope, or in other words if the deductions from the theory and the results of observation or experiment are in complete concordance it must be accepted as *true*; but if it accounts for *some* only of observed phenomena, it must be regarded as a mere unproved *hypothesis* possessing a greater or lesser degree of *probability*, while if there be a complete discordance between the postulates of the hypothesis and the facts of observation the hypothesis must be rejected as untenable; most if not all of the great scientific theories now generally accepted have been built up through the formulation and examination in this wise, of one or more—oftimes many—working hypotheses.

The Copernican theory, Kepler's theory and laws of planetary motion and Newton's great theory of universal gravitation and his law thereof are now—and long have been—accepted, universally it may be said by the scientific world, because in the case of these the agreement between theory

and observation seems to be full and perfect, and they satisfactorily account for all the workings of that vast and complicated celestial mechanism, the solar system. But even these great and apparently firmly established concepts should they fail to account satisfactorily for any additional, or newly discovered phenomenon or fact of observation within their province, would be degraded from their exalted position and relegated to the ranks of more or less probable hypotheses, while they would be susperseded by any theory competent to explain satisfactorily the additional phenomenon or fact together with *all* those already thus accounted for by the now accepted theories; but so long have these famous fundamental theories been put to the crucial test aforesaid and so well have they met all the requirements of science in this respect, that such a contingency is exceedingly improbable and it is almost a certainty that they will maintain their preëminent position during all future time, or so long as the human race has its attention attracted by the phenomena of the heavens above it.

This criterion for either the rejection of any hypothesis or its acceptance and elevation to the dignity of a theory in the scientific, restricted sense of the latter word, is so well-known and recognized by students of science in all its various departments, not only in that of physics, that the statement thereof, above set forth may seem superfluous to some, but the treatment of certain topics to be discussed in subsequent parts of this paper will be such that it would be well for the general reader who may be interested in this subject to bear it in mind as it will enable him to the more readily comprehend, and the more critically analize, the present status of divers hypotheses and so-called theories of molecular physics.

The nature of matter, and its properties has been for ages a subject of much thought and speculation by philosophers and students of physics from the time that Democritus, the Thracian, in the fifth century before the beginning of the Christian Era, propounded his classical cosmic theory—or rather hypothesis—which asserts that all that exists is "*vacuum* and *atoms*" the latter being the indivisible, ever-existing, invisible ultimate particles of all things material—and even of *spirit*—endowed with magnitude and motion, and that "by this motion of the atoms the world was produced with all that it contains". Democritus conceived further, that the atoms are small, smooth and spherical, and that by their inhala-

tion and exhalation, life is maintained (not a bad concept even when viewed in the light of modern physiological science) but he made no distinction between the principle of life and the psychological faculties. While this concept of Greek materialistic philosophy (held and maintained a couple of centuries later by Epicurus and in the first century before the Christian Era, by the Roman writer Lucretius) is exceedingly simple, and even crude, it involved a germ that has in comparatively recent times, developed in the light of modern scientific thought, methods of research and discoveries, into the more definite and fully wrought-out theories, or hypotheses of "molecular physics" for even those most recently enunciated, postulate the existence in space of such ultimate particles called atoms, endowed with mass and motion, and constituting the foundation stones upon which is built up the structure of the material universe. In the year 1758 A. D., Boscovich, the eminent Italian astronomer, mathematician and physicist, in his famous work published in Vienna, and entitled "*Theoria philosophiæ naturalis redacta ad unicam legem virium in natura existentium*" propounded his mechanical or "kinetic" theory of the atom considered as a "center of force" and as an indivisible material point having mass and position in space, being capable of motion in a continuous path and by reason of its mass and motion, being endowed with both kinetic and potential energy. More recent theories regard the atoms as being grouped in systems or larger particles called "molecules", either in groups of two —or "duads"—or in higher multiples, but Boscovich's hypothesis is *monadistic*, and in this case the terms "atom" and "molecule" are synonymous. The English physicist John Dalton was the first one to propound (A. D. 1803) a truly *chemical* atomic theory which was the only one up to that time, that fully explained the facts of chemical combination in a satisfactory manner and which differs from all others in the vital point that it is a *quantitative* theory in respect to the constitution of matter whereas all others are simply *qualitative* views, and this theory of Dalton follows the doctrines of the Greek philosophers so far as it assumes that matter is not continuous but is composed of extremely small indivisible particles termed "atoms"; but it differs from those ancient hypotheses, and becomes a veritable *chemical* atomic theory, by reason of the fact that it also assumes that the atoms of different elements do not possess the same weights and asserts that the relation between their weights is rep-

resented by the "combining weights", of these elements, for instance, the weight of an atom of oxygen relative to that of an atom of hydrogen is 15.96 to 1, the latter weight being taken as the unit.

Although this atomic theory satisfactorily explains all the known laws of chemical combination the actual existence of atoms is by no means *positively* proved thereby, and it appears very unlikely that *chemical* considerations alone will ever effect the solution of this question. Nevertheless, there has been in recent times, a constantly accumulating array of physical phenomena bearing testimony which compels us to admit a limit to the divisibility of matter, and therefore to acknowledge the existence of atoms, most of these phenomena belonging to the domain of "molecular physics", and some of them being the capillary attraction of liquids, the diffusion of gases, the production of electricity by the contact of metals *et al.* Reasoning from the facts observed in the study of these subjects, physicists have come to the conclusion that matter is *discontinuous* and consists of myriads of molecules of exceedingly small magnitude, these molecules themselves being each a system or grouping of smaller particles–the atoms–and some physicists have even gone so far as to indicate the order of magnitude of these molecules under certain conditions. The first estimate of the diameter of a molecule of hydrogen gas under the normal conditions of pressure and temperature, was made in 1865 by the skilful physicist Loschmidt, from the mean path and molecular volume his result being very approximately $\frac{1}{63{,}000{,}000}$ of an inch, and in 1870 Sir William Thomsom (now Lord Kelvin), in the same manner not only, but also, by means of the thickness of the delicate films of soap-bubbles, and from electrical action between surfaces of copper and zinc, found the diameter of a molecule under the normal conditions, to be approximately, $\frac{1}{50{,}000{,}000}$ of an inch, a value about 25 per cent greater than that determined by Loschmidt.

Some years ago while working on the problem that has led me to the writing of this paper, I found by means of an original method differing entirely from those employed by the two physicists mentioned that under the normal conditions of pressure and temperature the diameter of a molecule of the atmospheric gases (or, rather a mean-diameter in the case of the several gases composing the atmospheric air) was to be

$\frac{1}{63,800,000}$ of an inch, a value agreeing with Loschmidt's results to within a small fraction of one per cent. Subsequently however, by the use of more numerous data, and with "checks" upon the work, I obtained a definitive value of $\frac{1}{73,600,000}$ of an inch for the diameter of a molecule of ordinary air. The minuteness of these molecules, or little spherical globules, can be well illustrated by comparing them with marbles or pellets, placed in a line, side by side, in which case there would be the enormous number of 73,600,000 in one linear inch, while the cube of this number would, of course, represent the number of such molecules included within a volume of only one cubic inch of air, this volume containing therefore, in round number 400 quintillions of molecules a number so great that it can be expressed most conveniently by a multiple of the power of 10 or by 4×10^{23} (a method of expression generally employed by mathematicians in computations involving numerical quantities of magnitudes so enormous); it is also equivalent to the figure 4 followed by 23 ciphers.

The fact that Loschmidt's determination, is for hydrogen, while mine is for atmospheric air, does not affect the comparison of results, because the "law of Avogadro" asserts that "under the same conditions of pressure and temperature, the number of molecules in any given volume is the same for all gases", and as the molecules are spherical, their diameters must be the same in all cases. The values derived for magnitudes of this kind are generally regarded even by the investigators themselves, as only comparatively rough approximations, so that the three determinations; viz, that of Loschmidt, Thomson and myself, are in sufficiently close agreement to corroborate the modern *physical* concept of the molecule. My determination differs by about 49 per cent from that of Thomson and by only about 15 per cent from that of Loschmidt, it being in each case less, but for reasons that will be stated in a subsequent part of this paper wherein among other matter, I will set forth my method of determination of the diameter of a molecule, and I feel that I am warranted in claming that my value of $\frac{1}{73,600,000}$ of an inch represents the true diameter of a molecule of any perfect gas to within not more than one per cent thereof.

The existence of the molecular condition of matter is like-

wise an essential condition of the mechanical theory of gases by means of which nearly every known mechanical property of gaseous matter can be explained on dynamical principles, and in this fact again, we have a confirmation of the real existence of molecules and of their component particles the atoms. As every chemical compound must consist of at least two elements the *molecule* of a compound must consist of at least two smaller particles that we may rationally regard as the *atoms*.

There are therefore two standpoints from which the profound and important question of the constitution or nature of matter as to its ultimate parts the atoms, and the molecules composed thereof, may be viewed, one of them being that of the *chemist*, as exemplified by the great Atomic Theory propounded by Dalton, and the other that of the *physicist*, as in the case of the investigation and determinations of Loschmidt and Sir William Thomson in the field of molecular physics, and this fact has caused some ambiguity and even apparent contradiction in statements regarding the fundamental postulates of several hypotheses concerning this question of the nature of matter. Thus the atomic theory of Dalton explains quite fully and satisfactorily the observed chemical phenomena within its province. It does not cover all mooted points, and it is even an open question whether the facts of chemistry, which led Dalton to the proposition of his atomic theory, are not explicable by some other equally tenable hypothesis. The theories, or views, of the eminent investigators in the field of molecular physics, Boscovich, Clausius, Loschmidt, Maxwell, Thomson, Stefan and others do not fully account for *all* the known phenomena within their scope, although the labors of these physicists have materially advanced the lines of knowledge in this field of science, and established a firm base of operations from which further progress may be expected. Therefore neither the chemical, nor the physical theories are fully adequate in their respective provinces to the task of explaining satisfactorily all the phenomena therein and moreover they are not in concordance *inter se*, the chemist and the physicist each viewing the atoms and the molecules at a different visual angle. Consequently, if under the above stated conditions, we were to apply the "criterion" (as to the sufficiency of any hypothesis or theory) described on a preceding paper with *all its rigor*, the aforesaid theories—even that of Dalton valuable as it is to chemistry—would be found wanting and they would logically

be classed simply as more or less probable hypotheses or views. In this connection only so-called "gross matter"—gases, liquids and solids—has been considered, and when we come to the question of the ultimate constitution of the luminiferous ether that hypothetical fluid which serves as a medium for the transmission through space af all kinds of radiance—we find it practically *in nubibus*, deeply immersed in clouds of doubt.

This matter is known to us only by its action in the propagation of radiant energy, and by using the observed value of said energy in the form of heat radiated by the Sun, in a given time as a "known quantity," together with the known value of the velocity of light and certain other numerical factors in an algebraic equation. The density of this matter may be determined and this has been done by several mathematical physicists among them the late Professors J. Clerk Maxwell, in England, and De Volson Wood, in the United States—but these several determinations are not concordant *inter se* and therefore the problem as to the true nature or condition of this ethereal fluid must be regarded as unsolved thereby.

Some of the greatest physicists of modern times—especially Sir William Thomson—who have profoundly studied this most interesting and important subject have regarded the matter of the luminiferous ether as *continuous* or not composed of discrete particles or of separate and distinct molecules and atoms while others have looked upon it as *molecular* and therefore *discontinuous*, thus practically classifying this ether, as to its ultimate constitution, with gaseous fluids.

Even the famous "vortex-atom" theory propounded by Sir William Thomson and founded upon some concepts of Helmholz in regard to vortex motion in an *ideally perfect* fluid,—homogeneous, continuous, incompressible and of invariable mass, rotational motion therein being also continuous in space and time, the persistent vortex-rings in said fluid performing the functions of the atoms in the case of other atomic theories—could not meet the crucial test of the rigorous application of the "criterion" aforesaid, and the same statement applies with equal if not greater force to the "electronic theory ot matter" advanced only a few years ago by another eminent English physicist Professor J. J. Thomson.

In view of the facts, stated on the few preceding pages, in this connection, it is very obvious that this momentous question is by no means to be regarded as *res adjudicater* or that the last word has been spoken thereon; the cause is one *adhuc coram judice*.

Therefore when in seeking a satisfactory explanation of the peculiar phenomenon exhibited by the incandescent electric lamp and which attracted my attention sixteen years ago, I found it essential to acquire a more definite and accurate knowledge of the nature and constitution of the ultimate particles of the invisible matter within the bulb of the lamp, than that at hand, and to formulate a "working hypothesis" that should lead me to some general and satisfactory theory of molecular physics that would meet all the rigorous requirements of the "criterion" aforesaid. I felt that it was scientifically permissible for me to make at least an essay in this direction after a critical examination of the several theories or hypotheses on this subject now extant.

At that time I was—and had long been—deeply interested in astronomical science particularly in that branch thereof known as "physical astronomy", and in the mathematical processes of Analytical Mechanics whence the principal, fundamental formulæ of physical astronomy have been derived, as well as in that portion of mechanics devoted to molecular physics. I had also, for a long time been engaged in the practical work of computation of the "elements" of planetary cometary and other orbits, and of those variations of these "elements" caused by the mutual gravitative action of the masses of the members of the solar system relative to that of the Sun, which variations are called "perturbations" so that in seeking for a more accurate knowledge of the nature of the ultimate particles of the matter operating in the causation of the special phenomenon aforesaid and of the modes of motion of these particles *inter se* the idea very naturally suggested itself to me to formulate a working hypothesis based on the principles of analytical mechanics in regard to bodies moving in orbits under the "laws of central forces" or in other words to regard the molecules of this matter as normally composed of *at least* two smaller particles or atoms (as will be demonstrated subsequently—there are very many duad groups of atoms in a molecule) of equal mass revolving with great orbital velocity around a center equidistant between them, their motions being governed by a force of attraction exerted between them and varying as the inverse square of the distance of each from the center aforesaid, the orbital velocities of the atoms being according to Kepler's "third law of planetary motion" which asserts that, in such orbits "the squares of the times of revolution are proportional to the cubes of the mean distances," the latter being in the case of these molecules one-half the distance between the two atoms of

each duad—in other words, the radius of each molecule considered as a spherical shell. Under this concept the case is analogous to that of two bodies of a binary stellar system in which both bodies are of equal mass, and revolve in circular orbits around a center of attraction midway between them assuming the existence of such a system and by reason of this analogy I have denominated my concept "an astronomical theory of the molecule".

My method of procedure was of course, purely tentative, at first and I confess that I had then but little expectation of obtaining any result very definite, tangible or valuable from a specific standpoint, but I had not proceeded very far along the line of investigation thus laid out before some definite and very significant facts were disclosed and for further research led me to an extension of my working hypothesis which seemed to me to satisfy the required conditions of concordance between theory and observation or the results of experiment in such a degree that I felt warranted in embodying a statement of it and the results flowing therefrom in a paper under the title, "Effects of Pressure upon the Transmission of Radiant Energy through Gaseous Media," and since this involved questions directly concerning the radiation of light and heat, and the density and pressure of the transmitting medium therefor, all these questions being more or less intimately connected with and of importance to astronomy and particularly to that special modern branch thereof known as "astrophysics" I communicated this paper to the magazine Astronomy and Astro-Physics, (of which periodical, POPULAR ASTRONOMY is an immediate successor) and it was published in the initial numbers (101 and 102) thereof in January and February 1892.

My research was gradually extended during subsequent years along the same lines and in the year 1895 was published the first part of my treatise, under the general title, "The Constitution and Functions of Gases, the Nature of Radiance and the law of Radiation", this containing a statement of the fundamental concepts of my theory as to the nature and constitution of the molecules and atoms of matter in the gaseous state—to which state all kinds of material substances are reducible; a statement of the dimensions and masses of the molecules and their component atoms, and the linear velocities of the latter in the atomic orbits within the molecule,—all in absolute measurements,—together with the mathematical method and formulae for the derivation of these

quantities; a mathematical treatment of the thermodynamics of gases under the concepts of my theory, and the development of an analytical expression for the "law of radiation," with an application of the latter to practical purposes, one of these applications being a determination of the effective surface temperature of the Sun, the density and pressure of the luminiferous ether by and through which the solar heat and light is transmitted to the Earth, and the candle-power radiated to us from the solar disk—all the results in this connection agreeing well with those of observation and experiment; furthermore in this part, a very probable cause of electrical and magnetic action was indicated. This part was followed in the same year by a short "supplement" containing some slight amendments, and additions to the matter of the first part, particularly in regard to gaseous pressure—a mathematical expression for the normal atmospheric pressure giving results agreeing with those of observation to within a very small fraction of one per cent, being formulated and set forth therein. In 1896 was published a second part—under the same general title—treating of the "terrestrial atmosphere" and its meteorological phenomena, with some references to subjects discussed in the first part aforesaid, and in 1897 a third part containing a discussion of the development of the solar system from the primitive condensing gaseous nebula, and the development therefrom—through a secondary process—of the Earth and the other planetary bodies with special reference to past and present geological conditions of our globe, and the seismic phenomena observable thereon—(a subject of present popular, as well as scientific, interest on account of recent occurrences in this line) the various comparisons between theory and observation, being sufficiently concordant in all cases. This matter was put in print mainly for preservation, and with a view toward further study of the subject and in the course of a revision made thereof, quite recently, additional very significant and important results flowing directly from the concepts of my theory, and amply verified by those of observation and experiment, were obtained. Some of these relate to the question of the specific nature of "gravity", and others to the ultimate cause of electrical and magnetic phenomena, particularly to the source of "terrestrial magnetism" and by reason of the latter fact I have denominated my theory "an electronic theory of matter" as well as "an astronomical theory of the molecule"—the two constituting the gener-

al title of this paper which I have communicated to POPULAR ASTRONOMY for the same reason, and in the same manner, that my first concepts on this subject were communicated to its predecessor, Astronomy and Astro-Physics, A specific statement of the fundamental concepts of my theory and its relation to other theories that have been propounded in the past—particularly that of vortex-atoms and "the electronic theory of matter" quite recently advanced by Professor J. J. Thomson as aforesaid will be set forth in a following part of this paper.

To be Continued.

MATHEMATICS NEEDED FOR THE STUDY OF PRACTICAL ASTRONOMY.

W. W. PAYNE.

FOR POPULAR ASTRONOMY.

We have spoken of Algebra and Geometry as branches of mathematics needed for the study of Practical Astronomy in No. 8 of the current volume of this publication page 493. Although briefly considered the essentials of these branches were set forth with some suggestions regarding methods of getting them for a working basis either in advanced pure mathematics or in the broad field of Practical Astronomy. It was also urged that the student keep in mind one thing, always, and that is, the *object* of his work in every step of it that he takes. This thought may be put in the form of three questions: 1. Why is this step taken? 2. How is it to be done to give full understanding of method and proof? 3. What is gained by it?

Such thinking will put the student at his work in the right way, and help him to do it well. It will show him the difference between using a rule in its exact language, or a formula from memory and the use of the principles that are stated in the form of a rule or a formula. In the one case the student will learn to adapt the principle needed to the particular case in hand, and he will be able to verify his work because he knows how to check it, and in cases of approximation, he can know, generally the limits of uncertainty in his results, a very useful thing to know, for it defines uncertainty by exact knowledge on every side of it.

In the other case which deals wholly with given rules and formulæ, the student can not be very sure of much of any

thing he does while at work in the higher mathematics and its applications.

The next branch of Pure Mathematics to claim our attention is that Trigonometry. The history of this study is one of very great interest. Ideas of its principles were known by Egyptian mathematicians one thousand years before the Christian Era, and how much earlier no one now can say certainly. In the British Museum, forming part of the Rhind collection, is Ahme's hieratic papyrus. The translation, by Egyptologists, of this piece of old history is indeed interesting to mathematicians for it gives considerable information about the knowledge of mathematics known to that ancient people. There are other very early records from Babylonia and Egypt recently discovered waiting for the translator to decipher them.

History gives Hipparchus and Ptolemy the credit of creating trigonometry. It is known that they had tables of chords which were essentially the same as our tables of sines, but we do not know how they solved plane and spherical triangles because their books containing that information are lost. Hipparchus lived about 125 B. C., while Ptolemy died 168 A. D. These men were both noted astronomers in their time, the former laying a rational basis for Astronomy as a science in observation and the latter writing a treatise on Astronomy, called the *Amalgest* which was regarded as authority for more than one thousand years. Trigonometry was by these scholars regarded as a part of Astronomy, and its creation a necessity for the prosecution of that science. The schools of the Greeks, Arabs and the Hindoos down to the fifteenth century held the same view of the relation of Trigonometry to Astronomy.

It was not until near the close of the Renaissance, about the middle of the seventeenth century that the development of Trigonometry, as a branch by itself began. It is not probable that one who studies this branch of the mathematics can very well realize now the difficulties that a student would meet in trying to get at what had been discovered by the scholars at that time.

Then there were no elementary text-books. What had been written and published could be found only in large volumes on astronomy or mathematics under some other more general title. This, too, was before the time of printing; all books were made by hand, and they were expensive. Only the scholars could read them. This is the time when

the notation of Trigonometry was taking shape and the progress made in developing the branch was exceedingly slow. It was not until the time of John Bernoulli, Demoivre, Euler and Lambert that Trigonometry was complete enough to become an instrument in the hands of scholars for mathematical analysis.

In modern times this noble branch of study has been so thoroughly developed and extended that it easily falls into two grades: 1. That which is named Elementary Trigonometry and, 2. Higher Trigonometry, more often called Elliptic Functions. We will speak of the elementary part first, and then briefly notice the present state of the development of Elliptic Functions.

Trigonometry treats of the numerical measurement of angles and of triangles. The first thing that may catch the attention of the beginner is in regard to the notation used and the unit values employed in measurement. The notation is that of Algebra largely, which is symbolic in form, with that which belongs to the trigonometric functions which is syncopated in kind. To the advanced scholar it is a wonder that such a mixed notation should ever have been chosen in the first place, and still more that it should have kept its place so long and apparently with so much satisfaction in scientific circles. A symbolic notation like that of Algebra could have been chosen easily and the work in Trigonometry then would have been much abbreviated; it would have formed a neater page for proofs and computations and it would have been a saving in mental energy in long and difficult investigations. This change may come some time. As it is now in the expression,

$$y = \tan x$$

the student thinks of y as a straight line which is the ratio of two other straight lines themselves the ratios of two other straight lines each of which is divided by a constant R, the radius of some given circle. If illustrated geometrically, the thought is not difficult for any one to grasp, so that a concise symbol for tan x would be an improvement. The other thought is in regard to the units employed in Trigonometry. If we follow the ideas and the limits of the Euclidean Geometry in our thinking and illustrations we must use linear units and units of angle or arcs often in the same equation. A clear knowledge of how these units are related in the fundamental formulæ of Trigonometry is

very essential to the beginner. Unless he knows the exact meaning of the symbols for each kind of unit, he can not apply the fundamental relations of elementary Trigonometry either readily or certainty. It will be well to give close attention to this feature of the notation that the practical uses of it may be both certain and exact. One of the best exercises the writer knows of in this matter is to find the lengths of arcs of any number of degrees, minutes and seconds, in terms of the radius, by the use of seven-place logarithms as far as the unit radius.

In the elementary course, the eight fundamental relations with their meaning, as seen in the ordinary geometrical figure, should be thoroughly committed to memory. To do this well, one may first learn all the properties of the *sine* and the *cosine*, and from these mentally derive the properties of all the other six functions from the geometry of the circle which is itself so simple that the student will not find it a hard task to do it thoroughly so that mental uses of them will be quick and easy always afterward. The same thing should be said about the signs and values of the trigonometric functions at the end of each of the four quadrants and at each of the octants of the circle, for the computer in logarithmic work in trigonometry should not have to turn to a book to find out any one of these common things any more than he would look the multiplication table up to find the product of five times seven.

The beginner ought also to make himself familiar, in the same way, with the precepts regarding the change of the signs of the trigonometric functions and their corresponding angles or arcs for the computer is always on his guard when he changes the sign of an angle to know what effect that will have on the sign of the trigonometric function belonging to the same angle which he is about to use.

From what has been said, it may be well for the student to think out the conditions when the following theorems can be used, and thereby learn the limits of approximation for different kinds of problems:

$$\sin x : \sin y = x \sin 1'' : y \sin 1'' = x : y.$$
$$\tan x : \tan y = x \tan 1'' : y \tan 1'' = x : y.$$
$$\begin{aligned} \text{Arc } x &= [8.2418774]\, x^\circ \\ &= [6.4637261]\, x' \\ &= [4.6855749]\, x''. \end{aligned}$$

In the expressions containing the brackets the numbers en-

closed are the logarithms of that part of the radius equal in length respectively to one degree, one minute and one second of arc.

This brings us to notice the uses of logarithms in much of the work of trigonometry. A student who has done but little work of a practical kind in trigonometry is aware of the large use that is made of logarithms in nearly all such computations. He also has learned that a knowledge of the principles of a system of logarithms is not enough to give him a ready use of this instrument in mathematical work or investigation. He must know the meaning of them so thoroughly and so familiarly that he will be able to tell when to use tables of three, four, five, six or seven places most economically for the degree of accuracy in result needed for the work in hand.

If the student has not the advantage of an experienced instructor to guide him in preparing for practical work, he should have a hand-book which contains suggestions and directions for the best forms, methods of using formulae and the degree of accuracy needed. If he should depend on good text-books he would find this information in connection with the various subjects of which the texts treat. A good hand-book which aims to cover these points generally is preferable. We have found Holman's Discussion of the Precision of Measurements helpful. There are others that probably are fuller and even better adapted to the wants of the beginner than this.

To indicate a little more exactly what we mean, we would say for example, in preparing to compute results from formulae by the use of logarithms, the different parts the formula may be arranged in vertical columns, so that the successive steps of the computation will easily follow one another before the logarithms from the tables are read into the work. When this skeleton is completed, then consider the degree of accuracy desired before choosing the logarithmic tables for the work. For example if tenths of degrees is the limit of accuracy which is needed or can be reached by the conditions of the problem, then use three-place tables. If minutes of arc are wanted, then four-place tables are sufficient. If seconds of arc must be found six-place tables are sometimes better than five. But if the computer wishes to reach results accurate to the tenths of a second of arc he should use seven-place tables. Any student who will take

the trouble to settle such a point as this by mastering the principle in his trigonometry will have little trouble after it in choosing the proper tables for any piece of work in hand if he knows in the outset what degree of precision he should aim at in the different parts of any given problem.

To show how easily this knowledge may be acquired, an incident may be cited which seems to cover the point fairly well. A student at Carleton College in post-graduate study in applied mathematics had gained a little experience in computing the orbit of a comet. Later that student went to one of the great universities in this country, and there took up the same kind of work under a leading instructor who directed the use of seven-place logarithms in which four places would have given the utmost degree of accuracy in the given example. The best of it all was, the student knew enough about the practical uses of tables to choose the right ones and thereby save time and labor. This is important for the young computer is easily discouraged if he does not know well just what he is doing at every step.

Just before giving this incident we were speaking of the tabular skeleton form of the trigonometric parts of the formula to be used in computation. Every step in the operation is written down preferably on squared paper. The next step is to read the logarithms from the tables into the skeleton form. In doing this the student, from the outset, must acquire a firm habit of accuracy in reading figures from the tables and in performing the simple operations of addition and subtraction of the logarithms. To do this the student should always read numbers and perform operations twice over at each step while the attention is on it, that he may then and there do his very best to be correct in the results he obtains. It will take more time to do work at first in this way but accuracy in it is more important than rapidity. The rapidity will come later when a habit of accuracy is well formed.

It would take too much space to give all the interesting points in trigonometry that might be spoken of as bearing on the preparation of the student for its uses in the study of the higher mathematics and the astronomy. What has been said in the few things already noticed is sufficient to indicate in a general way how other parts of the study might be undertaken in a helpful and a masterly way,

The best book on plane and spherical trigonometry that

the writer has used, or knows of, in the English language, is not one recently written, but it is one more than twenty-five years old. Its title is, A Treatise on Plane and Spherical Trigonometry, by William Chauvenet, and published by J. B. Lippincott & Co., of Philadelphia. The latest impress we have noticed showed that the book had passed through the ninth edition. The reason this book is adapted to the wants of students seeking preparation for advanced studies in any line of science where the trigonometry is largely used is that it has been prepared by a mathematician thoroughly acquainted with the real wants of such students, and also that he has shown the ability, as a scholar, to meet those wants in a remarkable way.

The person that will take that text and go through it patiently and perform all the exercises in it understandingly will have a preparation in trigonometry that will fit him well, for advanced study very generally. Many hints, suggestions, forms of work, checks, short methods, labor-saving devices, neat applications and apt transformations are found in different parts of this text.

THE RED SPOT ON JUPITER.

W. F. DENNING.

For Popular Astronomy.

Observations by those well-known students of planetary detail Mr. A. Stanley Williams and the Rev. T. E. R. Phillips show that another remarkable acceleration of motion has occurred in the Red Spot during the past summer.

In May 1907 the longitude of this marking was about 24½°. It had increased to this value from 16½° on August 8, 1906 when my first observation (after Jupiter's conjunction with the Sun) was made. In September 1907 the longitude of the spot was 18½° so that it had lost 6° since the previous May and the rotation period was

$$9^h\ 55^m\ 39^s.$$

The singular circumstance about this recent increase of velocity is that the S. temp. spot which has on several occasions when in conjunction with the Red Spot apparently quickened its speed, was on the opposite side of the disk during the past summer and could hardly have influenced the motion of the latter object unless we assume

that when the two markings are in opposition there is a similar effect, though of smaller extent, to that observed at conjunction.

It will be for further observations to decide this point and fortunately for such an investigation both the red spot and S. temp. spot appear likely to remain visible for a long period in the future. The S. temp. marking has been conspicuous since Major Molesworth first recognized it in February 1901 and though it has exhibited remarkable variations in size and aspect it has shown no trace of decadence. Its rotation period is $9^h\ 55^m\ 19^s$ while the mean period of the red spot since 1898 has been $9^h\ 55^m\ 40^s.6$ thus conforming exactly to the adopted rule employed for System II in Marth-Crommelin's ephemerides published in the *Monthly Notices* of the R. A. S.

Bishopston, Bristol.
October 15, 1907.

REVIEW OF SOLAR OBSERVATIONS MADE AT ALTA, IOWA, DURING THE YEAR 1906.

DAVID E. HADDEN.

For Popular Astronomy.

The following observations are in continuation of those published in this journal from year to year, the last series being for the years 1904 and 1905 published in Popular Astronomy, No. 140. The instrument was a Brashear 4-inch refractor.

The principal characteristics of the record for 1906 are:

1. A slight decrease in the mean daily number of groups, spots and faculæ.

2. Marked fluctuations of activity followed by periods of distinct decline. Spots of the first magnitude being present in January, March, July, August and December, with minima in February, September and October.

3. The increase in number of spotless days; at least eight days in October were free from spots.

4. The greater frequency of spots in the northern hemisphere which was noted in 1905 has continued with a slight relative numerical increase this year.

Reviewing the record for the present solar cycle so far, the observations this year appear to point to the maximum as having been passed during the latter months of the year

1905 and that the more gradual and steady decline towards the minimum has now set in.

The following table exhibits the numerical results of the year's observations:

Months 1906	No. of Observing Days	Average No. of Groups	Average No. of Spots	Average No. of Faculae	Average No. Groups N. Lat.	Average No. Groups S. Lat.	No. of Spotless Days.
January	11	4.1	15.0	4.0	2.5	1.6	0
February	10	2.8	7 1	3.5	2.2	0.6	0
March	7	4.7	16.6	4.0	2.6	2.1	0
April	15	4.0	16.3	3.9	3.0	1.0	0
May	22	3.5	15.8	3.0	3.0	0.5	0
June	23	4.2	17 0	3.3	3.4	0.8	0
July	25	7.1	25.1	3.5	5.5	1.6	0
August	23	3.3	10.9	3.1	1.7	1.6	0
September	21	3.7	14.0	2.9	1.9	1.8	0
October	20	1.0	4.6	3.0	0.3	0.7	8
November	10	3.1	13.2	2.4	1.7	1.4	0
December	11	4.3	23.8	3.1	3.0	1.3	0

Some of the principal features of each month are as follows:
JANUARY—The Sun's disk was fairly well spotted during the month, in the first half the spots were mainly small and few, but in the latter half the spot zones both in north and south latitudes were well marked with small and large spots and groups which followed each other in processions.
FEBRUARY and MARCH—Owing to unfavorable weather which prevails in this location during the winter months the records for these months were seriously interrupted by clouds and cold waves. Fair sized spots were present during the month of February and first half of March, during the latter half of March some groups of the first magnitude made the transit of the visible disk and at the close of the month spots were well scattered in both spot zones north and south across the disk.
APRIL—The groups of the last week in March were still present during the first week but were smaller in size, and after the middle of the month were fewer and more scattered.
MAY—A revival of activity set in this month and from the 12th to the close of the month numerous and large spots were noted, sudden outbursts accompanied by marked spectroscopic reversals of the hydrogen and helium lines were observed in some of the groups from the 13th to the 18th.
JUNE—Mainly small but numerous spots were present during the first ten days after which a decline began reaching a minimum on the 17th and during the afternoon of that date the disk was clear of spots, this did not continue long however, for the following day a revival of activity

began which continued to increase daily during the balance of the month and in the closing days the spot zones, especially in the northern hemisphere were studded with spots.

JULY—The great activity noted during the latter half of June continued nearly all of the present month. During the first decade two large spots were present, one in the south and the other in north latitude, the latter being the larger and more persistent having made the second rotation of the visible disk from July 25 to August 7 and a third appearance from August 22 to September 3 but gradually diminishing in size until it disappeared at the west limb.

On July 27th five spotlets appeared in a faculae region which entered the southeast limb the preceding day and by the 29th had assumed large proportions constituting a spot group which during its visibility became a group of the first magnitude. It consisted of a large leader spot with bridged umbra and curious whorls of penumbra studded with circling nuclei during the 30th, later merging into larger penumbra and changing umbrae; a bright bridge again crossed the spot on August 3rd which continued until it passed out of sight on the 5th. It returned to the east limb about the 20th but hardly recognizable as the same disturbance.

AUGUST—With the exception of the spots already noted in the early and closing days of the month the interval between was characterized by comparative quiescence, only small and transitory spots being visible.

SEPTEMBER—This month also witnessed a gradual decline in activity, the spots being mainly all small and devoid of any special interest.

OCTOBER—Was remarkable for a still further decline which reached a minimum on the 17th when the disk became free from spots and remained so until the 29th with the exception of an occasional veiled spot, this is the longest period of quiescence since September 1903 when eleven days were noted without spots.

NOVEMBER—During the first half of the month a fairly large spot in south latitude made the transit of the disk, its umbra underwent daily interesting changes. Conspicuous and numerous spots appeared in the northeast quadrant during the closing days of the month which continued visible in the first week of December.

DECEMBER—A spot of the first magnitude was visible in

the south hemisphere from the 12th to the 24th and during the same period an extended stream of small spots was in the northern hemisphere. The year closed with a number of smaller groups still lingering on the disk. For comparison the results obtained here during the past sixteen years are given in the following table—

Years	Days of Observation	Average Annual Number of Groups	Spots	Faculae	Total No. of Spotless Days.
1891	257	2.9	14.9	3.6	24
1892	205	5.6	34.0	4.1	0
1893	177	6.6	36.6	4.1	0
1894	139	5.6	30 0	3.4	0
1895	149	5.2	30.5	3.5	0
1896	197	3.2	17.8	2.9	5
1897	198	2 2	11.0	2.3	29
1898	234	2.1	11.0	2.4	30
1899	259	1.1	4.8	1.5	108
1900	255	0.7	3.4	1.0	134
1901	269	0.25	0.9	0.3	212
1902	230	0.37	2.0	0.5	163
1903	230	1.65	7 8	1.9	32
1904	172	3.10	13.25	3.14	0
1905	202	4.00	18.18	3.9	2
1906	198	3.80	15.00	3.3	8

Alta, Iowa.

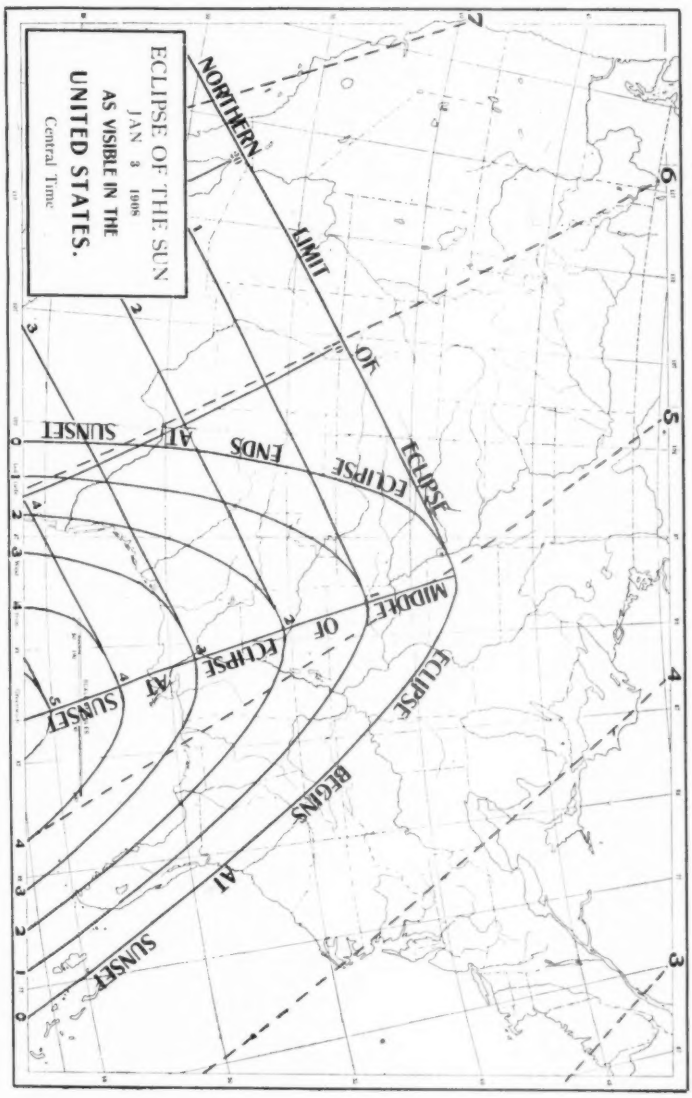
THE SOLAR ECLIPSE OF JANUARY 3, 1908 AS VISIBLE IN THE UNITED STATES.

Wm. F. RIGGE, S. J.

For Popular Astronomy.

The solar eclipse of January 3, 1908, while a total one along the equatorial region of the Pacific Ocean, will be visible in the United States as a partial eclipse under very unfavorable conditions. The accompanying map will make us acquainted with the circumstances.

The curves marked as the beginning, middle and end of the eclipse at sunset and as its northern limit are sufficiently intelligible without explanation. The parallel curves marked 1, 2, 3, 4, 5, show the tenths of the Sun's diameter eclipsed at sunset, with this difference that for places to the east of the line which indicates the middle of the eclipse at sunset, the eclipse will be increasing, and decreasing, for places west of it. The lines 1, 2, 3, 4, parallel to the northern limit line, denote the maximum obscuration at the middle of the eclipse, while the two lines at right angles to them marked 10 and 20, show the height in degrees of the Sun above the horizon at this time. Finally the broken lines 3, 4, 5, 6, 7, indicate the central times of sunset.


ECLIPSE OF THE SUN
JAN 3 1908
AS VISIBLE IN THE
UNITED STATES.
Central Time
NORTHERN
LIMIT
OF
ECLIPSE
ENDS
AT
SUNSET
MIDDLE
OF
ECLIPSE
AT
SUNSET
ECLIPSE
BEGINS
AT
SUNSET

A couple of examples will illustrate the use of the map. At Montgomery, Alabama, the Sun will set at 4:50 when 0.18 eclipsed, and the eclipse will then still be increasing but abruptly ended by the Sun's setting. At Austin, Texas, the Sun will set at 5:40 when 0.16 eclipsed, the eclipse will then be decreasing, its maximum having been 0.25 at an altitude of about six degrees.

Creighton University, Observatory.
Omaha, Nebraska.

ON A NEW MEANS OF SHARPENING CELESTIAL PHOTOGRAPHIC IMAGES; AND APPLIED WITH SUCCESS TO MARS.

PERCIVAL LOWELL.

Among the many devices, combination of which has made possible the successful photographing here of Mars, enabling the canals of the planet to print their own record on the film, next to steadiness of air none is more vital than the approximate monochromatization of the light got by the use of a suitable color screen placed in the cone of rays before that reaches the sensitive plate. For by means of this artifice is attained the practical unity of focus essential to definition. It was by application of the principle that Ritchey secured his excellent pictures of the Moon which marked so great an advance in celestial photography; and a color screen of much the same character was first employed here by Mr. Lampland in photographing Mars, one specially designed by Mr. Wallace for the color-curve of the 24-inch.

The planet, however, is a much more difficult subject for photography than our satellite, inasmuch as the markings desired are of a finer texture. To reveal the canals involves the getting of a definition far surpassing that sufficient to make beautiful portraitures of the Moon; as the scale upon which the two pictures are made is enough to show. Now several things militate against the obtaining of a sharpness of delineation of the degree required for the registering of planetary detail. Chief of course is unsteadiness of the air which rarely permits approach to perfection in the image. Next comes the chromatism of the telescope. While lastly, linked for bad effect with both, is the relative insensitiveness

and granularity of the photographic plate. It is the latter's comparative slowness of action and coarseness of grain that renders the eye the more delicate instrument in decipherment of the sort. Nevertheless, owing to a possible prolongation of the effect and to the accentuation of contrast produced by the film, the camera has recently done some surprising work in the case of Mars in registering what, without its prompting, the eye had failed to detect.* The main proposition, however, remains true. For accuracy of form in the Martian markings one must stand commended to the eye. for the finer detail comes out by flashes and prolonged exposure results only in a blur.

To reduce the time of action to its shortest compass is thus one of the essentials to success. On the other hand to shorten the time is to reduce the light, and a modicum of light is necessary to securing an image in which the finer detail shall show. Here again the plate offers a bar in the coarseness of its grain as compared with the markings to be registered, since to magnify the image much is prohibitive to the getting of any revelation at all. What has been said will give some idea of the difficulties to be overcome.

It is evident, then, that two points must be assured. Enough light action on the one hand and approximate monochromatism on the other. To attain these two results has been one of Mr. Lampland's exhaustive studies in this field for the last four years. He has carefully tested all kinds of plates and we have even gone so far as to try to get new plates made for us.

During this time Mr. V. M. Slipher had been engaged in experiments upon bathing plates for extension of action into the red. His remarkable success led me to a new departure. Mr. Slipher's plates were for spectroscopic purposes but in considering the color-curve of the 24-inch objective, it occurred to me that another use might be made of them to wit: that unity of focus might be more nearly approached without loss of light by bathing the plates in suitable solutions for prolongation of their sensitiveness into the red and then cutting off the light of greater focal length toward the blue by a color-screen specially contrived for the purpose. By previous color-screens the light admitted had been made

* On one of my plates at this opposition a canal stood recorded where none had previously disclosed itself. On searching for it visually the next night, the canal was seen for the first time.

COLOR CURVE OF LOWELL REFRACTOR.

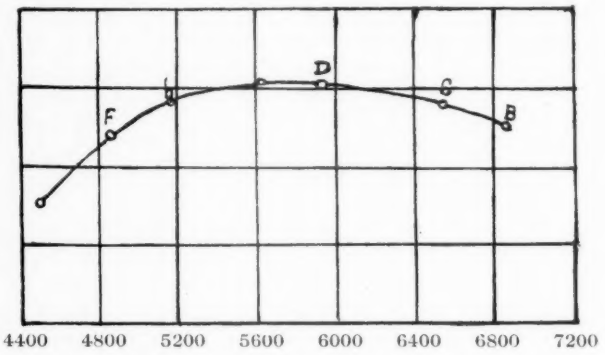


FIGURE 1.

The ordinates represent focal distances in millimeters, the abscissae, wave lengths of the spectral rays.
(Positions determined by Mr. V. M. Slipher.)

up of rays extending from wave-lengths $\lambda = 4660$ or $\lambda = 4700$ to the extreme limits red-wards of the sensitive plate which in the case of unbathed plates stopped in the yellow; even Cramer's Instantaneous Isochromatic only going to $\lambda = 6000$.

Now, according to the color-curve of the 24-inch objective, and for that of Clark's glasses generally, the light waves for $\lambda = 4600$ are not brought to the same focus as those for $\lambda = 6000$, falling in the case of the 24-inch some 12-mm beyond it. Light from them, therefore, is worse than useless in the formation of the image where form is what is sought. For though they add to the intensity, they detract from the definition. To secure the maximum effectiveness the problem consisted in integrating, as it were, the illumination within such limits as to give sufficient light with the least focal deviation between the different rays. Their intensities had to be summed, weighted for their respective focal lengths.

Investigation on my part indicated $\lambda = 5000$ as the blue-ward limit of the light to be admitted to attain the best result. Accordingly I asked Mr. Wallace to construct for us both a solid and a liquid filter to cut off all the rays up to that point, which, with some difficulty for precision, he very successfully did.

To comprehend the principle involved it is necessary to

consider in connection the focal color-curve of sensitiveness of the several plates.

The color-curve of the objective is given in Figure 1, the ordinates representing the focal length, the abscissae the wave-lengths of the several spectral rays. It will first be noticed that F, $\lambda = 4861$ and B, $\lambda = 6875$ have the same focus, the result striven for by Clark in the grinding of the glass; and secondly that any light of less wave-length than F has a focus further out, increasingly so as the wave-length is decreased. Also that the curve is flatter, or in other words, the focal distances of neighboring rays differ less from one another in the region of the yellow or about $\lambda = 5600$ than in any other part of the spectrum. The nearer the rays to be used are, therefore, to this minimum focus the less the resulting image will be blurred, and especially must the rays at the blue end be excluded as the focal curve falls much more rapidly on that side than on the red.

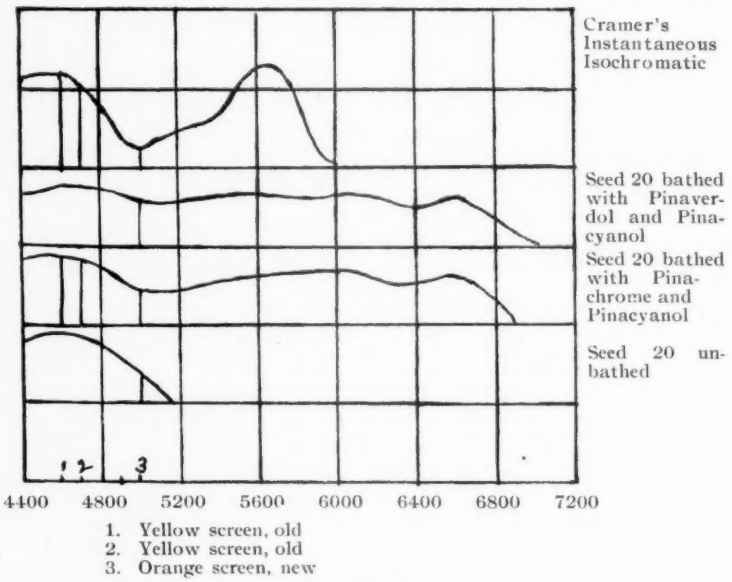
Turning now to the combination-bathed plates and selecting two, we perceive one bathed with Pinaverdol and Pinacyanol, the other with Pinaverdol, Pinacyanol and Pinachrome (Figure 2); that their curves of sensitiveness run approximately level from a minimum at about $\lambda = 5000$ to $\lambda = 6500$ and $\lambda = 6800$ respectively, or in the case of the latter from about F to B, and of the former from F to C; both including far more of the red rays than the unbathed plates. By bathing, therefore, enough rays could be secured at the red end to offset the loss of light from cutting out those between $\lambda = 4600$ and $\lambda = 5000$ and at the same time secure a less deviation in their integrated focal lengths. With the plate bathed in Pinaverdol and Pinacyanol, one should be able theoretically to obtain as much illumination as with an unbathed one, after cutting out all the rays below $\lambda = 5000$ and, with a total deviation in the extreme focal lengths of only 4.4 mm as against 12.4 mm, or but a third as much not to mention the fact that in the unbathed the intensity of the out-of-focus rays is relatively much greater. The conception was theoretically sound; it only remained to see if it would work in practice.

The screen was first tried on Seed "23" plates bathed in a solution of Pinachrome and Pinacyanol under Mr. Slipher's able manipulation, and then exposed by me at the telescope. Owing to the unavoidable introduction of other factors, increased length of exposure principally due to the relative

slowness of the Seed "23" further accentuated by the bathing, the result was not successful, Mr. Slipher being of the opinion that the developer used, Pyro, had some hand in the failure. Whatever the cause, desire to get photographs of the planet induced me to defer the experiment in this form, though I hope to take it up later. In the meantime I applied the device to Cramer's Instantaneous Isochromatic plates and this time with success.

The curve of sensitiveness of the Isochromatic plates, Figure 2, is peculiar. Though the plate is called the Iso-

CURVES OF SENSITIVENESS OF PHOTOGRAPHIC PLATES.


Cramer's Instantaneous Isochromatic
Seed 20 bathed with Pinaverdol and Pinacyanol
Seed 20 bathed with Pinachrome and Pinacyanol
Seed 20 unbathed
1 2 3
4400 4800 5200 5600 6000 6400 6800 7200

1. Yellow screen, old
2. Yellow screen, old
3. Orange screen, new

FIGURE 2.

chromatic Instantaneous, it is neither isochromatic nor instantaneous and stands justified of its name only on the syllogistic ground that two negatives make an affirmative. But its very lack of isochromatism proved its salvation. For, in it we note two maxima, one about $\lambda = 4600$ and another at $\lambda = 5650$: while a minimum exists at $\lambda = 5000$. The theoretic difference here, between the action of of the two screens, is evident at a glance. The yellow or old one admits out-of-focus rays of theoretically great intensity be-

tween $\lambda = 4600$ and $\lambda = 5000$ which the orange screen at $\lambda = 5000$ entirely cuts out.

Exposing a plate of this kind on Mars in our usual way a method by which fifty or more images are taken consecutively on a single plate, in a few minutes, I took half the number behind the old screen and then replacing it by the new one, took as many more, both sets being exposed equally, about two seconds being given to each image. The plate was then developed as a whole. The result stood self-confessed. The detail came out sharper in the images taken with the orange screen than with those taken with the yellow, although the images of the former were not quite so dense on the average, showing that in their case a slightly longer exposure would generally be necessary.

In order to be sure that the outcome was not due to change in the seeing during the interval, short as was the time between the first image and the last, I later exposed another plate in the same way and to the like conclusion. The orange screen gave the sharper definition while the exposure time for equal effect was about as 7 to 6.

The bettering of the image was much greater than I had anticipated and than the spectrograms taken with the two color-screens respectively, and here reproduced, would show. I regret that it is out of the question to reproduce satisfactorily the images showing the success of the theory, for the improvement, though evident in the original prints, loses too much in definition by reproduction processes.

This improvement has come too late to affect our results at this opposition but I trust to put it in practice at the opposition of two years hence.

Lowell Observatory Bulletin, No. 31.

FIFTEEN NEW VARIABLE STARS IN HARVARD MAPS, NOS. 15, 18, AND 27.

EDWARD C. PICKERING.

The systematic search for bright variable stars, by the method described in Circular 127, has already led to the announcement, in Circulars 127, 129, and 130, of nearly 100 new variables, and has furnished much material for the discussion of the distribution of such objects. Three addi-

tional regions, each 30° square, have been examined this autumn, by Miss Leavitt, and a summary of the results is given in Table I, in the same form as Table I of Circular 130. The successive columns give the number of the plate, in the Map of the Sky, the right ascension and declination of its center, the number of new variables discovered, the total number found in the examination, including those previously known, the proportion of new variables, the whole number known to exist at the end of the examination, the probable total, the proportion of the probable total found, the probable number unknown, and the proportion probably unknown. A description of the method of obtaining these quantities in the different columns is given in Circulars 127 and 130.

TABLE I.

NUMBER AND DISTRIBUTION OF THE VARIABLES.

No.	Region.	New Variables.	Total Found.	Proportion New.	All.	Probable Number.	Proportion Found.	Probable No Unknown.	Proportion Unknown.
	h °								
15	10 + 30	5	9	.56	10	11	.82	1	.09
18	16 + 30	6	14	.43	22	28	.50	6	.21
27	10 0	4	7	.57	11	16	.44	5	.31

The following known variables were re-discovered during the examination:—In Region 15, W Cancri, R Leonis Minoris, S Leonis Minoris and V Leonis; in Region 18, S Coronae Borealis, R Coronae Borealis, X Coronae Borealis, R Serpentis, 155229, R U Herculis, W Coronae Borealis, and g Herculis; in Region 27, R Sextantis, R Leonis, and *094501*. The asteroid, Hebe, was also found, near opposition, on Plate AM 4046, taken January 25, 1906, exposure 60^m.

Before Harvard numbers could be assigned to the new variables, it was necessary to correct an error in Circular 130, Table II. The variables to which the Harvard numbers 2973 and 2974 were there assigned were already known as XZ Cygni and 200949, while 221995, to which the Harvard number 2982 was given has been announced as suspected by Müller and Kempf in Potsdam Publications, **14**, 429, and **17**, 293, and as variable by Backhouse in West Hendon House Publications, III, 113. The Harvard numbers given to these three stars are here withdrawn, and are assigned, instead, to the first three of the new variables, given in Table II.

TABLE II.

NEW VARIABLES.

Designation.	Harvard No.	Constellation.	DM.	R. A. 1900.	Dec. 1900.	Bright.	Faint.	Range.
				h m s	° ′			
090007	2973	Hydra	− 7° 2715	9 0 48	− 7 51.5	9.0	11.5	2.5
091906	2974	Hydra		9 19 53	− 6 21.8	10.0	<11.5	>1.5
093126	2982	Leo	+ 26° 1981	9 31 5	+ 26 41.4	9.0	10.6	1.6
094223	3007	Leo Minor		9 42 33	+ 33 45.2	9.5	11.5	2.0
094627	3008	Leo	+ 27° 1818	9 46 25	+ 27 22.3	9.8	10.4	0.6
094802	3009	Sextans	+ 2° 2264	9 48 16	+ 2 31.6	8.9	9.6	0.7
100039	3010	Leo Minor		10 0 7	+ 39 51.4	11.0	11.8	0.8
100224	3011	Leo	+ 24° 2183	10 2 8	+ 24 28.9	9.0	9.8	0.8
100709	3012	Hydra	− 9° 3017	10 7 24	− 9 49.5	9.1	9.8	0.7
152636	3013	Bootes		15 26 47	+ 36 8.1	10.2	11.0	0.8
155436	3014	Cor. Borealis	+ 36° 2672	15 54 47	+ 36 17.9	9.6	10.6	1.0
160325	3015	Hercules	+ 25° 3031	16 3 14	+ 25 10.3	8.8	9.7	0.9
163238	3016	Hercules	+ 38° 2803	16 32 28	+ 38 10.1	8.4	9.7	1.3
164917	3017	Hercules	+ 17° 3117	16 49 54	+ 17 0.0	10.0	10.8	0.8
165722	3918	Hercules	+ 22° 3048	16 57 15	+ 22 36.7	10.0	<11.0	>1.0

The discovery of variable 190965, H 2971, should be credited to Mrs. Fleming, as she had marked it on two spectrum plates previously to the publication of Circular 130. These plates are I 33685, taken November 23, 1905, and I 34173, taken August 15, 1906, and in each case the record was "Mc 5 d, var.?" Later, the variability was confirmed on chart plates by Miss Wells. In Table II, the designation is followed by the Harvard number, constellation, number in the Bonn Durchmusterung, right ascension and declination for 1900, brightest and faintest magnitudes observed, and observed range. The variables *090007*, 093126, and 094233 appear to be of the Algol type.

Harvard College Observatory. Circular 133.

NON-SCREEN ORTHOCHROMATIC AND PANCHROMATIC PLATES BY BATHING.*

E. KÖNIG.

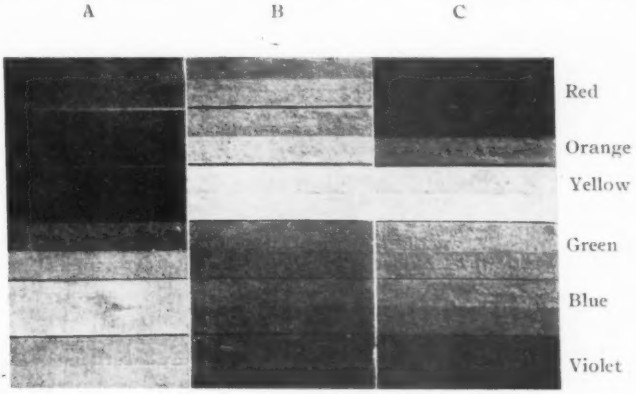
It is well-known that in all orthochromatic and panchromatic plates the blue sensitiveness peculiar to silver bromide is always much greater than that for the less refrangible rays produced by the color-sensitizer, so that it is necessary to use a yellow filter during exposure to reduce the action of the blue rays. Since the use of the yellow screen is always somewhat inconvenient, many manufacturers have, during the last few years, placed on the market orthochromatic plates which contain the screening yellow dye in the film, and have thus enabled the user to dispense with the yellow screen during exposure. These plates are not always satisfactory, and I have therefore endeavored to find a method of making such plates by bathing ordinary plates. The results can be seen from the accompanying illustration.

There are not many yellow dyes which are suitable for this purpose, as there are several conditions to be fulfilled. The dye must be easily soluble in water, it must stain the gelatine, but must be easily washed out; it must not re-act with the sensitizer, nor be prejudicial to the keeping powers of the film. All these conditions are perfectly fulfilled by "filter yellow K," which is already well-known in England.

* The British Journal of Photography, Oct. 18, 1907.

To make the sensitizer 5 gms. of filter yellow K and 0.1 gms. of erythrosin should be dissolved in 600 ccs. of distilled water, and 300 ccs. of alcohol added. Methylated spirit may be used. In this solution, which will keep indefinitely, the plates should be bathed for two or three minutes and dried without washing. The bath may be used over and over again, and only needs filtering from time to time. The plates are always clean, free from streaks or spots, and will keep for three months unchanged.

I should not omit to mention it is not every plate that



EXPOSURE OF A COLOR CHART TAKEN WITHOUT A FILTER.

The green is composed of blue and yellow, and appears very bright, in consequence of the blue in the plate used.

A. Ordinary plate. B. Panchromatic plate with rapid filter yellow (pinacyanol and erythrosin). C. Orthocromatic plate, erythrosin only as a sensitizer.

can be sensitized with erythrosin, and, unfortunately, I am not in a position to name any English plates that are suitable, though doubtless many are.

In developing some of the yellow dye remains in the developer, whilst some in the fixing bath. After a short washing the plate is quite free from stain. Neither the developer or fixing bath is spoiled by the yellow dye.

My attempts to make a panchromatic plate with pinachrome and "filter yellow K" were not satisfactory. The sensitizing with pinachrome is strongly reduced by the yellow. On the other hand, I succeeded in making a bath with pinacyanol for panchromatizing by adding to 300 ccs. of the above-named bath 2 ccs. of a 1: 1,000 pinacyanol

solution. Plates thus prepared show an extraordinary action in the yellow, orange, and red; only the green sensitiveness left something to be desired.

The sensitiveness of the plates, sensitized with erythrosin, to daylight is about 0.4 times less than the sensitiveness of the unbathed plates.

COMET *d* 1907 (DANIEL).

O. C. WENDELL.

For Popular Astronomy.

This interesting naked-eye comet was discovered by Mr. Zaccheus Daniel of the Observatory at Princeton, N. J., on the morning of June 10, 1907. When found it was quite conspicuous in a telescope of 3 inches aperture. In a larger telescope it appeared nearly round with a condensation at the center, the nucleus being somewhat faint and star-like. On July 4 it was considerably brighter with a more pronounced nucleus and a short tail. A little over a week later the comet was visible to the naked eye. It then resembled a somewhat faint star with a tail about one degree long. In the early part of August the nucleus was still brighter, the tail also being quite bright and about two and one-half degrees long. An idea of its length may be gained from the fact that the full Moon is one-half a degree in diameter, so that the tail appeared about five times as long as the diameter of the full Moon. The comet at that time was quite conspicuous and attractive in appearance. It was, however, only visible in the morning, being best seen about 3 o'clock A. M. This increase in brightness was mainly due to the fact that the comet was approaching both the Sun and the Earth with considerable rapidity. About August 1, however, it passed its point of nearest actual approach to the Earth, being then about 70 million miles distant. On September 4 it passed perihelion, at which time it was 48 million miles distant from the Sun. Its theoretical light began to diminish about August 23.

As a matter of interest I have put together in the following table the right ascensions and declinations of the comet and Sun for a number of dates, separated by intervals of about a month, and extending from the time of discovery up to May 1, 1908,—also the distances of the comet from the Sun and Earth on these dates.

The first and last six places given in the Table I have calculated from Dybeck's orbit which seems to be the best at hand, while the rest of the numerical data has been collected from various sources, but depending mainly on the same orbit. This orbit was computed by Dybeck from three observations but the first and last were separated by nearly a month so that while the positions for the last dates of the table can not be rigorously exact from the fact that so long a time has elapsed since the time of the last observation used in the orbit, yet the table subserves the purpose intended which was to give a condensed summary of our recent knowledge of the comet, the apparent relative positions of comet and Sun, the varying distances of the comet from the Sun and from the Earth, and also a small amount of the comet's future history. An inspection of the table shows that, although the comet's distance from the Sun steadily increases,

Date.	Comet						Millions of miles from		Sun			
	R. A.			Dec.			Sun	Earth	R. A.		Dec.	
1907	h	m	s	°	′				h	m	°	′
June 9	23	47	33	− 1	8.4		165	150	5	6	+ 22	53
July 8	1	29	50	+ 7	0.		128	100	7	7	+ 22	34
Aug. 2	4	41	35	+ 16	27.3		83	70	8	47	+ 17	57
Aug. 18	7	7	6	+ 16	47.0		60	81	9	48	+ 13	20
Sept. 1	8	50	45	+ 13	34.6		48	105	10	39	+ 8	32
Sept. 25	11	4	47	+ 5	47.1		67	150	12	5	− 0	35
Nov. 1	13	5	21	− 3	24.1		124	204	14	23	− 14	13
Dec. 1	14	5	6	− 7	25.1		168	232	16	26	− 21	43
1908												
Jan. 1	14	45	49	− 9	12.0		211	243	18	43	− 23	5
Feb. 1	15	6	31	− 8	56.1		250	241	20	56	− 17	21
Mar. 1	15	5	3	− 7	1.6		285	234	22	49	− 7	33
Apr. 1	14	42	19	− 3	51.0		321	237	0	43	+ 4	35
May 1	14	12	20	− 1	9.9		354	263	2	34	+ 15	6

its distance from the Earth remains nearly constant for some time about the beginning of 1908, due to the relative motions of the comet and Earth. Its theoretical brightness on May 1, 1908 is 0.07, that at discovery being unity, so that it will probably be more or less visible in large telescopes for some time to come. I have not computed the radiant point for meteors as this has already been done by Kritzinger of Berlin. He finds that on July 27 the comet was in heliocentric latitude −3.′9 and its distance from the Earth's orbit was 0.068. This corresponds to a distance of 6.3 million miles which is quite a near approach. The radiant point for meteors connected with the comet he gives as R. A. $23^h\ 8^m$

and Dec. + 3°. The Earth passes the point of near approach September 12 and from the lateral spreading of meteors in the orbit, some might very well be attracted and encountered. It may be added that Schmidt found an active radiant from September 3 to September 14 in R. A. $23^h\ 4^m$ and Dec. + 3°.

Cambridge, Mass.

THE DOUBLE STARS DISCOVERED AT THE DEARBORN OBSERVATORY BY PROFESSOR GEORGE W. HOUGH.

S. W. BURNHAM.

For Popular Astronomy.

A most valuable and interesting addition to the literature of double stars has just been issued by the Flower Observatory of the University of Pennsylvania, as Volume III of its publications, under the title *Catalogue and Re-Measurement of the 648 Double Stars discovered by Professor G. W. Hough by Eric Doolittle*, pp. 186. These stars were discovered by Professor Hough with the 18½-inch Clark refractor of the Dearborn Observatory during the last twenty-five years; those prior to 1887 at the observatory in the city of Chicago, then connected with the old University of Chicago, and subsequent to that time at the new observatory at Evanston attached to the Northwestern University. The performance of this instrument has been demonstrated in many different ways by its use in observations requiring the highest degree of optical perfection, and any one, now or hereafter, undertaking the measurement of many of these discoveries will find that however large the objective may be, one of perfect figure will be indispensable. There was a time when it was at the head of all the telescopes of the world in the diameter of the objective, and its power for the most delicate and difficult test observations. That place in the front rank has long since been surrendered to the larger refractors furnished by the same eminent opticians, but the exquisite definition of the 18½-inch object-glass of nearly fifty years ago has never been excelled by the great Clarks or by any one else. The most sensational double star discovery of any age was made with this telescope when Alvan G. Clark in 1862 found the long suspected and sought for companion of Sirius, before the great refractor was started on its journey to Chicago; and astronomical science has been advanced

by a continuation of observations in this department by the Director and others during the past thirty years. With a single exception, no telescope in the world has so brilliant a record in the discovery of stellar systems; while in addition to this, Professor Hough has kept up an unbroken series of observations of the planet Jupiter for more than a quarter of a century, thus furnishing a longer record of careful and accurate measurements than that made by any other astronomer, past or present.

The double stars discovered by Professor Hough as already stated, for the most part, are of a close and difficult class, and most of them difficult or impossible to measure with a much smaller aperture. The result was that many of them had not been subsequently measured at all. The important work of re-examining and a re-measuring the entire list was undertaken by Mr. Doolittle in 1901. He says in the introduction to this work:

"When making up a new observing list for the Flower Observatory in 1899, it was decided to include all Hough pairs in which prior measures had indicated motion, as well as those which did not seem to have been adequately measured elsewhere. It soon became evident that the entire list had been remarkably neglected. Of the 490 pairs which have now been published for thirteen years, there are but seventeen which have been systematically observed, and of these no less than eleven are certainly entirely fixed. Altogether, 383 of these pairs have never been measured except by the discoverer himself, and of these 199 have only been measured the year of discovery, and 43 only on a single night, or not measured at all.

If we examine the entire published list of 622 pairs we find that only 23 have been measured more than five times; that 494 have only been measured by Hough; and that 66 have been measured on a single night only, that is, on the night of the discovery, or not measured at all. If the measures of the Greenwich observers and of Professor Aitken are excluded, there remains no less than 568 of the 622 pairs which have never been measured except by Hough. Yet the discoveries include a large number of close pairs in which motion might reasonably have been expected, and not a few in which, from Hough's measures, motion had actually been indicated.

Since all of Professor Hough's discoveries were made with the 18½-inch of the Dearborn Observatory, their observation

seemed particularly appropriate for the 18-inch telescope of the Flower Observatory. It was believed that it should be possible to re-measure each of the pairs, and thus to make the present series of observations a complete one.

Work was systematically begun on these stars in 1901, and in the course of two years the list was nearly completed. But there were many stars with which the results of my measures differed from the first obtained, and a number of others which, because they were so difficult that they could only be observed on unusually good nights, were not finished. To obtain later measures of these, the present publication has therefore been delayed until now. Nearly all stars showing decided change have been re-measured since 1904, and no pair remains which is not either measured, or of which I am not reasonably certain that it is single in this telescope at this time."

The arrangement and completeness of the work is above all criticism. No pair is measured on less than three nights and most of them on five or six. The care and thoroughness with which every part of the work has been done is obvious on every page. No better evidence could be offered of the optical excellence of the 18-inch telescope made by Mr. Brashear than its use in so successfully carrying out this long series of difficult observations.

This work was a much needed one, and a proper tribute to the reputation and memory of one who has perhaps been longer in astronomical work than any other in the country. In bringing together these discoveries, scattered in many volumes of the periodical in which they were originally printed, Mr. Doolittle has done for Hough what Hussey has done for Otto Struve stars, Lewis for the Struve stars, and the writer for the Burnham lists. Future observers of any of these stars will appreciate these several compilations as well as the new measures which bring the history of these systems down to the present time.

SOME ASTRONOMICAL CONSEQUENCES OF THE PRESSURE OF LIGHT.

J. H. POYNTING.

The experiments of Lebedew and Nichols and Hull have proved conclusively that light presses against any surface upon which it falls, and the extraordinarily accurate experi-

ments of Nichols and Hull have fully confirmed Maxwell's calculation that the pressure per square centimeter is equal to the energy in the beam per cubic centimeter.

A clearer idea of the effect of light or radiation pressure is obtained by thinking of a beam of light as a carrier of momentum. We then see that not only does it press against a receiving surface, but also against the surface from which it started.

Some experiments by Dr. Barlow and myself appear to bring to the front this conception of light as a momentum carrier. If a beam falls on a black surface at an angle to the normal, there should be a tangential stress along the surface. An experiment was described in which light fell on a blackened disk at the end of a torsion arm, the disk being at right angles to the arm*. The disk was pushed round by the tangential stress. The experiment was carried out in a partially exhausted vessel, but the residual air was a source of disturbance by convection and radiometer effects. A better experiment was made by suspending a disk of mica blackened beneath, about two inches in diameter by a quartz fiber, the disk being horizontal and suspended from its center. When a beam of light fell at 45° on a part of the disk, the horizontal component of the beam being at right angles to the radius to the part where it fell, the disk moved round through the combined effects of convection, radiometer action and the tangential stress. When the beam was allowed to fall on the same place at 45° on the other side of the vertical, convection and radiometer action were very nearly as before, but the tangential stress was reversed. The difference in torsion in the two cases was twice that due to the tangential stress. An experiment with prisms† was also described.

Regarding a beam of light as a momentum carrier, it is easily seen that if the receiving surface has velocity u towards the source and the velociey of light is U, the pressure is increased by the motion by the fraction u/U. If the velocity is reversed, the pressure is decreased by this fraction. This is the "Doppler reception effect."

If the source is moving, and we assume that the amplitude of the emitted waves depends on the temperature and

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* *Phil. Mag.*, IX (1905), p. 169.

† *Ibid.* p. 404.

nature of the source alone, it can be shown that the pressure on the source is $U/(U \mp u)$ of its value when the source is at rest. This is the "Doppler emission effect."

In considering the consequence of light pressure, it is necessary to know the temperature of a body exposed to the Sun's radiation. It can be shown that a small black particle, at the distance of the Earth from the Sun, has about the mean temperature of the Earth's surface, say 300° Abs., and that the temperature of the Sun is about twenty times as high, say 6000° Abs. The temperature of the particle varies inversely as the square root of its distance from the Sun.

The direct pressure of sunlight is virtually a lessening of the Sun's gravitation pull. On bodies of large size this is negligible. On the Earth it is only about a forty-billionth of the Sun's pull, but the ratio increases as the diameter decreases, and a particle one forty-billionth of the Earth's diameter, and of the same density, would be pushed back as much as it is pulled in, if the law held good down to such a size. If the radiating body is diminished, the ratio of gravitation pull to light push is similarly diminished, and it can be shown that two bodies of the temperature of the Earth's surface and the Earth's mean density would neither attract nor repel each other, if their diameter was about one inch. The consequence of this on a swarm of meteorites is obvious. It is probable that this balancing of gravitation and light pressure must be taken into account in the motion of the particles supposed to constitute Saturn's rings.

When we consider the motion of a small particle round the Sun, we have, first, the direct pressure lessening gravitation. If it has density equal to that of the Earth and diameter one-thousandth of an inch, the lessened pull at the distance of the Earth will imply a lengthening of the year by nearly two days. Secondly, the Doppler emission effect comes into play, for the particle crowds forward on its own waves emitted in front, and draws away from those emitted behind, so that there is increase of pressure in front and a decrease behind. Thus there is a force resisting the motion. The particles will then tend to fall inwards in its orbit, and in the case considered, about 800 miles in the first year. It would probably move in a spiral into the Sun, and reach it in less than 100,000 years. A

particle one inch in diameter would reach the Sun from the Earth in less than a hundred million years.

The Doppler reception effect will not come into play in a circular orbit, but in an elliptic orbit it acts as if it were a force resisting change of distance, and therefore it tends to make an elliptic orbit even more circular.

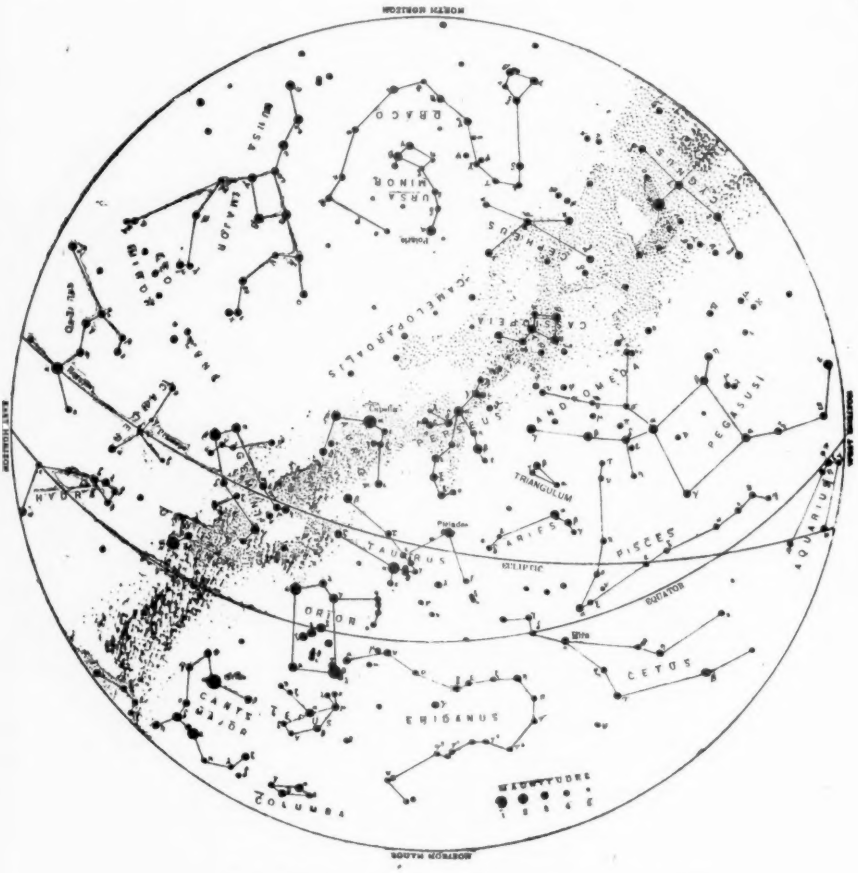
Applying these considerations to a comet regarded as a swarm of small particles coming into our system, a sorting action will at once begin. The smaller particles will have their period of revolution lengthened out more than the larger ones, and they will tend to trail behind. The Doppler emission effect will damp down the motion, and again, more markedly with the smaller particles, and all will tend to spiral into the Sun. The Doppler reception effect will tend to destroy the ellipticity of the orbit, more especially with the smaller particles, and ultimately the particles of different sizes may move in orbits so different that they may not appear to belong to the same system. In course of time they should all end in the Sun. Perhaps the zodiacal light is due to the dust of long dead comets.

It appears just possible that Saturn's rings may be cometary matter which the planet has captured, and on which these actions have been at play for so long that the orbits have become circular.

PLANET NOTES FOR JANUARY 1908.

H. C. WILSON.

Mercury will be at superior conjunction January 14 and so will be invisible to the eye this month.



THE CONSTELLATIONS AT 9:00 P. M., JANUARY 1, 1908.

Venus is evening star, easily identified in the southwest for about two hours after sunset. Her brightness will increase slowly during this month, and the phase is nearly full.

Mars will be at the ascending node of his orbit crossing the ecliptic on January 27, having already crossed the equator on January 11. He is near the meridian between four and five o'clock so that he may be studied

in the early evening. The apparent diameter of the disk of Mars is now only seven seconds, so that the finer markings cannot be readily seen.

Jupiter will be at opposition January 29, and is a splendid object for study after midnight. The Earth is near the plane of the orbit of the satellites, so that their apparent motions are back and forth in almost straight lines.

Saturn is interesting now from the fact that its rings are turned so nearly edgewise to us that only a very faint trace of them can be detected. It can be seen in the early evening but is too low in the southwest for the best conditions.

A telegram sent out from Lick Observatory October 28 announced that prominent bright knots were visible in Saturn's rings, two east and two west, symmetrically placed. Another telegram, from Lowell Observatory November 7 reads as follows: "Condensation in Saturn's rings confirmed here and measured repeatedly. They are visible, symmetric and permanent. Outer situated near outer edge ansa B, inner at middle of ansa C. Conspicuous relative gap also detected and measured at 1.56 radius from center planet. Ring easily seen; placed further south from shadow at west than east."

Uranus will be at conjunction with the Sun January 4 and so will be invisible this month.

Neptune will be at opposition January 4 and is therefore in best position for study for the year. The position of Neptune for January 1 is R. A. $6^h\ 58^m\ 41^s$, Dec. $+\ 21°\ 55'$.

Occultations visible at Washington.

Date 1907	Star's Name	Magnitude.	IMMERSION. Washington M.T. h m	IMMERSION. Angle f'm N. °	EMERSION. Washington M.T. h m	EMERSION. Angle f'm N °	Duration. h m
Jan. 8	30 Piscium	4.7	6 09	93	7 10	203	1 01
13	BD.+16° 569	6.2	7 14	54	8 41	256	1 27
13	δ^3 Tauri	4.3	15 21	85	16 16	261	0 55
14	Mayer 198	6.3	8 56	135	9 40	192	0 44
16	NEPTUNE	...	17 11	94	17 48	228	0 37
18	η Cancri	5.4	9 00	86	10 21	284	1 21
18	39 Cancri	6.5	14 22	105	15 45	294	1 23
18	40 Cancri	6.5	14 27	111	15 50	288	1 23
22	V Virginis	4.2	10 45	127	11 54	278	1 09
27	θ Libræ	4.4	13 33	90	14 26	316	0 53
29	B. A. C. 6088	5.7	17 28	99	18 34	289	1 06

COMET AND ASTEROID NOTES.

Elements of Comet *a* 1907.—In *A. N.* 4205 Mr. E. Tringali of Rome gives the following parabolic elements of the comet *a* 1907, from observations on the dates March 11, 22 and Apr. 11:

$$T = 1907\ \text{Mar.}\ 19.1667\ \text{Berlin m. t.}$$
$$\left.\begin{aligned} \pi &= 54°\ 16'\ 32''.0 \\ \Omega &= 97\ \ 10\ \ 03\ .2 \\ i &= 141\ \ 39\ \ 47\ .2 \end{aligned}\right\} 1907.0$$
$$\log q = 0.412118$$

Elements of Comet *d* 1907.—In *A. N.* 4205 Professor E. Millosevich gives the following parabolic elements of the comet *d* 1907, depending upon observations at Rome on the dates June 16, July 18 and August 22:

$T = 1907$ Sept 3.98231 Berlin m. t.
$\omega = 294°\ 22'\ 41''.2$
$\Omega = 143\ 02\ 50\ .1$ 1907.0
$i = 8\ 58\ 09\ .1$
$\log q = 9.709592$.

Ephemeris of Comet *d* 1907.

[By H. H. Kritzinger in *A. N.* 4208].

		α 1907.0 h m s	δ 1907.0 ° ′	log *r*	log Δ	ΔM
Dec.	1	14 05 42	−7 27.7			
	2	07 19	7 33.3	0.2614	0.3993	3.3
	3	08 55	7 38.7			
	4	10 30	7 43.9			
	5	12 03	7 49.0			
	6	13 35	7 53.9	0.2756	0.4038	3.4
	7	15 06	7 58.7			
	8	16 35	8 03.4			
	9	18 03	8 07.9			
	10	19 30	8 12.2	0.2893	0.4077	3.5
	11	20 56	8 16.3			
	12	22 21	8 20.4			
	13	23 44	8 24.4			
	14	25 06	8 28.2	0.3024	0.4111	3.6
	15	26 27	8 31.8			
	16	27 47	8 35.3			
	17	29 06	8 38.7			
	18	30 23	8 42.0	0.3150	0.4139	3.6
	19	31 39	8 45.2			
	20	32 54	8 48.2			
	21	34 08	8 51.0			
	22	35 21	8 53.7	0.3271	0.4162	3.7
	23	36 32	8 56.3			
	24	37 42	8 58.8			
	25	38 51	9 01.1			
	26	39 59	9 03.3	0.3387	0.4180	3.8
	27	41 05	9 05.4			
	28	42 10	9 07.4			
	29	43 15	9 09.3			
	30	44 18	9 11.0	0.3500	0.4194	3.9
	31	14 45 29	−9 12.6			

ΔM is the number which is to be added to the comet's magnitude when $r = 1$ and $\Delta = 1$ (about 6.0 mag.) in order to give its magnitude on a particular date.

Elements and Ephemeris of Comet *e* 1907.—The following elements and ephemeris of Comet *e* 1907 (Mellish) have been communicated by Rear-Admiral Asa Walker, Supt. U. S. Naval Observatory. They were computed by Miss Eleanor A. Lamson from observations made at Washington by Mr. Frederickson on October 15, 18, 21.

ELEMENTS.

Time of passing perihelion $= T =$ Sept. $14^d.872250$ 1907 G. M. T.
Longitude of perihelion $= \pi = 349°\ 27'\ 51''.3$
Longitude of node $= \Omega = 54\ 22\ 2\ .7$
Inclination $= i = 119\ 46\ 53\ .9$
Perihelion distance $= q = 0.985448$
Residuals (O−C): $\cos\beta\,\Delta\,\lambda = -0.'3$, $\Delta\beta = 0.0$

HELIOCENTRIC COÖRDINATES.

$x = r\,[9.850515] \sin(350°\ 22'\ 37''.5 + v)$
$y = r\,[9.984040] \sin(\ 64\ \ 25\ \ 25\ .1 + v)$
$z = r\,[9.877361] \sin(320\ \ 30\ \ \ 3\ .4 + v)$

EPHEMERIS.

G. M. T		α			δ			Light
	d	h	m	s	°	′	″	
1907 Nov.	6.5	5	53	20 8	+12	25	45	3.18
	8.5	5	22	33.0	+15	59	20	3.36
	10.5	4	48	46.5	+19	25	38	3.26
	12.5	4	13	21.9	+22	27	43	3.06
	14.5	3	38	6.1	+24	52	54	2.82
	16.5	3	4	44.3	+26	36	58	2.48
	18.5	2	34	31.9	+27	43	24	2.14
	20.5	2	8	5.2	+28	19	59	1.78
	22.5	1	45	26.2	+28	35	30	1.47
	24.5	1	26	17.7	+28	37	14	1.20
	28.5	0	56	44.0	+28	19	27	0.84
Dec.	2.5	0	35	54.9	+27	52	3	0.58

Brightness of October 15, taken as unit.

Astronomical Bulletin No. 316.
Harvard College Observatory,
Cambridge, Mass. Nov. 7. 1907.

Elements and Ephemeris of Comet *e* 1907 (Mellish).—In the *Lick Observatory Bulletin* No. 124 Mr. R. T. Crawford and Miss Estelle Glancy give new elements of Comet *e* 1907 with an ephemeris extending from November 5 to December 31. The elements depend upon observations on the dates October 15, 19 and 30. The representation of the observations is close. It appears from the ephemeris that the comet was brightest on November 9, being then 3.15 times as bright as when discovered. Its motion during November has been rapid carrying it northwestward through Orion, Taurus, and Aries. It is now in Pisces and during December will pass westward through the arm of Andromeda into Pegasus. Its light is rapidly diminishing and by the end of December will be only one-tenth of that at the time of its discovery. The diagram (Frontispiece) shows the relative positions of the Earth and comet, and the reader will easily see from this why the comet is now waning so rapidly. In the diagram the comet's orbit is represented as being in the plane of the paper and the Earth's orbit is projected upon that plane. The parts of the Earth's orbit indicated by the broken line are beyond the plane of the comet's path.

ELEMENTS OF COMET *e* 1907.

$T = 1907$ Sept. 14.46317 Gr. M.T.
$\omega = 294\ \ 32'\ 03''$
$\Omega = \ 54\ \ 33\ \ 50$
$i = 119\ \ 40\ \ 48$
$q = 0.984110$

EPHEMERIS FOR GREENWICH MIDNIGHT.

1907	True α			True δ			log Δ	Brightness.
	h	m	s	°	′	″		
Nov. 5	6	08	57.6	+10	26	06	9.6494	2.91
7	5	40	34.4	13	53	24	9.6298	
9	5	08	53.0	17	22	19	9.6186	3.15
11	4	34	49.7	20	37	01	9.6175	
13	3	59	54.7	53	22	32	9.6268	2.84
15	2	25	52.1	+25	29	47	9.6453	

1907	True α	True δ	log Δ	Brightness.
	h m s	° ′ ″		
Nov. 17	2 54 13.0	+26 57 55	9.6711	2.18
19	2 25 54.4	27 52 18	9.7017	
21	2 01 17.7	28 21 00	9.7350	1.52
23	1 40 16.8	28 31 54	9.7696	
25	1 22 31.1	28 31 21	9.8041	1.04
27	1 07 34.4	28 23 56	9.8380	
29	0 55 00.7	28 12 48	9.8709	0.72
Dec. 3	0 35 31.7	27 46 48	9.9327	
7	0 21 37.4	27 22 04	9.9889	0.37
11	0 11 37.8	27 01 40	0.0399	
15	0 04 26.0	26 46 22	0.0862	0.21
19	23 59 17.1	26 35 59	0.1283	
23	23 55 40.6	26 30 07	0.1668	0.13
27	23 53 15.1	26 28 16	0.2021	
31	23 51 45.3	+26 30 03	0.2345	0.09

Brightness Oct. 15 = 1.00.

Numbering of Recently Discovered Asteroids.—In *A. N.* 4205 Dr. J. Bauschinger gives permanent numbers to thirty-four of the minor planets which were discovered during the years 1906 and 1907. This brings the total number of asteroids, for which the observations have been sufficient to determine the elements of their orbits up to 635. Fifteen of those which were at first thought to be new and were given temporary numbers have been identified with asteroids already known. For about seventy-five more the observations thus far published do not furnish sufficient data to determine the orbits.

Numbering of Recently Discovered Asteroids.

No.	Provisional Designation	Discoverer	Date of Discovery	Name.
602	1906 TE	Metcalf	1906 Feb. 16	Marianna
603	1906 TJ	Metcalf	Feb. 16	
604	1906 TK	Metcalf	Feb. 16	
605	1906 UU	Wolf	Aug. 27	
606	1906 VB	Kopff	Sept. 18	
607	1906 VC	Kopff	Sept. 18	
608	1906 VD	Kopff	Sept. 18	
609	1906 VF	Wolf	Sept. 24	
610	1906 VK	Wolf	Sept. 26	
611	1906 VL	Metcalf	Sept. 24	
612	1906 VN	Kopff	Oct. 8	
613	1906 VP	Kopff	Oct. 11	
614	1906 VQ	Kopff	Oct. 11	
615	1906 VR	Kopff	Oct. 11	
616	1906 VT	Kopff	Oct. 17	
617	1906 VY	Kopff	Oct. 17	Patroklus
618	1906 VZ	Lohnert	Oct. 17	
619	1906 WC	Kopff	Oct. 22	
620	1906 WE	Metcalf	Oct. 26	Drakonia
621	1906 WJ	Kopff	Nov. 11	
622	1906 WP	Metcalf	Nov. 13	
623	1907 XJ	Lohnert	1907 Jan. 22	
624	1907 XM	Kopff	Feb. 10	Hector
625	1907 XN	Kopff	Feb. 11	
626	1907 XO	Kopff	Feb. 11	
627	1907 XS	Kopff	Mar. 4	
628	1907 XT	Kopff	Mar. 7	
629	1907 XU	Kopff	Mar. 7	
630	1907 XW	Kopff	Mar. 7	
631	1907 YJ	Kopff	Mar. 21	
632	1907 YX	Kopff	Apr. 5	
633	1907 ZM	Kopff	May 12	
634	1907 ZN	Kopff	May 12	
635	1907 ZS	Lohnert	June 9	

VARIABLE STARS.

Approximate Magnitudes of Variable Stars on Nov. 1, 1907.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.	Name.	R. A 1900 h	m	Decl. 1900 °	′	Magn.
X Androm.	0	10.8	+46	27	10.6*d*	S Camelop.	5	30.2	+68	45	9.5*d*
T Androm.		17.2	+26	26	13.6*d*	RR Tauri		33.3	+26	19	11.4
T Cassiop.		17.8	+55	14	8.4*d*	U Aurigae		35.6	+31	59	8.8*d*
R Androm.		18.8	+38	1	11.1*d*	Z Tauri		46.7	+15	46	<11.6
S Ceti		19.0	− 9	53	12.5 *i*	U Orionis		49.9	+20	10	11.4*d*
Y Cephei		31.3	+79	48	9.0 *i*	V Camelop.		49.4	+74	30	11.4*d*
U Cassiop.		40.8	+47	43	14.0*d*	Z Aurigæ		53.6	+54	18	9.4
RW Androm.		41.9	+32	8	<13.5	X Aurigae	6	4.4	+50	15	8.8 *i*
V Androm.		44.6	+35	6	14.0*d*	V Aurigae		16.5	+47	45	11.6*d*
RR Androm.		45.9	+33	50	12.0*d*	V Monoc.		17.7	− 2	9	6.6
W Cassiop.		49.0	+58	1	9.4*d*	S Lyncis		35.9	+58	0	11.0*d*
RX Androm.		58.9	+40	46	13 *d*	X Gemin.		40.7	+30	23	8.6
U Androm.	1	9.8	+40	11	13.0*d*	W Monoc.		47.5	− 7	2	11.0
S Piscium		12.4	+ 8	24	<14	Y Monoc.		51.3	+11	22	9.6
S Cassiop.		12.3	+72	5	13.5 *i*	X Monoc.		52.4	− 8	56	8.0
U Piscium		17.7	+12	21	11.5 *i*	R Lyncis		53.0	+55	28	8.4
R Piscium		25.5	+ 2	22	11.5	RS Gemin.		55.2	+30	40	11.0
RU Androm.		32.8	+38	10	10.5 *i*	V Can. Min.	7	1.5	+ 9	2	9.9
Y Androm.		33.7	+38	50	13.0	R Gemin.		1.3	+22	52	9.0
X Cassiop.		49.8	+58	46	10.4 *i*	R Can. Min.		3.2	+10	11	10.6
U Persei		53.0	+54	20	10.4	RR Monoc.		12.4	+ 1	17	10.0
S Arietis		59.3	+12	3	13.6	V Gemin.		17.6	+13	17	<11.6
R Arietis	2	10.4	+24	35	12.6	S Can Min.		27.3	+ 8	32	7.8
W Androm.		11.2	+43	50	12.0*d*	T Can. Min.		28.4	+11	58	10.6
Z Cephei		12.8	+81	13	9.7 *i*	U Can. Min.		35.9	+ 8	37	10.0
o Ceti		14.3	− 3	26	3.5	S Gemin.		37.0	+23	41	<12
S Persei		15.7	+58	8	8.8 *i*	T Gemin.		43.3	+23	59	10.6
R Ceti		20.9	− 0	38	8.2*d*	R Cancri	8	11.0	+12	2	8.0
U Ceti		28.9	−13	35	12.4 *i*	V Cancri		16.0	+17	36	9.8
RR Cephei		30.4	+80	42	9.2 *i*	U Cancri		30.0	+19	14	<11.5
R Trianguli		31.0	+33	50	12.2*d*	S Hydrae		48.4	+ 3	27	<11.5
T Arietis		42.8	+17	6	9.4	T Hydrae		50.8	− 8	46	<10
W Persei		43.2	+56	34	9.4	W Cancri	9	4.0	+25	39	9.0
U Arietis	3	5.5	+14	25	13.6	Y Draconis		31.1	+78	18	13.0*d*
X Ceti		14.3	− 1	26	9.8*d*	R Leo. Min.		39.6	+34	58	9.5 *i*
Y Persei		20.9	+43	50	9.8*d*	R Leonis		42.2	+11	54	8.5
R Persei		23 7	+35	20	9.6 *i*	V Leonis		54.5	+21	44	11.5*d*
Nov. Per. 2		24.4	+43	34	13.3*d*	R Urs. Maj.	10	37.6	+69	18	7.0
S Formacis		41.9	−24	42	8.5	T Urs. Maj.	12	31.8	+60	2	10.5 *i*
U Eridani		46.2	−25	16	11.5	RS Urs. Maj.		34.4	+59	2	13.5
T Tauri	4	16.2	+19	18	10.0	S Urs. Maj.		39.6	+61	38	11.6*d*
R Tauri		22.8	+ 9	56	11.8*d*	T Urs.Min.	13	32.6	+73	56	10.5 *i*
W Tauri		22.2	+15	49	12.6	R Can. Ven.		44.6	+40	2	8.8 *i*
S Tauri		23.7	+ 9	44	<13	U Urs. Min.	14	15.1	+67	15	8.5 *i*
T Camelop.		30.4	+65	57	13.2*d*	S Bootis		19.5	+54	16	11.2d
RX Tauri		32.8	+ 8	9	11.0	V Bootis		25.7	+39	18	10.0 *i*
X Camelop.		32.6	+74	56	9.6 *i*	R Camelop.		25.1	+84	17	13.6*d*
V Tauri		46.2	+17	22	12.4*d*	R Bootis		32.8	+27	10	10.0 *i*
R Orionis		53.6	+ 7	59	12.2	S Serpentis	15	17.0	+14	40	10.6*d*
R Leporis		55.0	−14	57	9.0	S Coronae		17.3	+31	44	12.5*d*
V Orionis	5	0.8	+ 3	54	10.4	S Urs.Min.		33.4	+78	58	10.2*d*
T Leporis		0.6	−22	2	8.5	R Coronae		44.4	+28	28	6.0
R Aurigae		9.2	+53	28	8.8 *i*	X Coronae		45.2	+36	35	10 *i*
S Aurigae		20.5	+34	4	11.6	R Serpentis		46.1	+15	26	9.8*d*
W Aurigae		20.1	+36	49	<13	V Coronæ		46.0	+39	52	12.0*d*
S Orionis		24.1	− 4	46	9.0*d*	— Coronæ		52.2	+29	32	13.3
T Orionis		30.9	− 5	32	9.6 *i*	R Herculis	16	1.7	+18	38	13.6*d*

Approximate Magnitudes of Variable Stars on Nov. 1, 1907—Con.

Name.	R. A. 1900. h m	Decl. 1900. ° ′	Magn.	Name.	R. A. 1900. h m	Decl. 1900. ° ′	Magn.
RR Herculis	16 1.5	+50 46	8.4 *i*	S Aquilae	20 7.0	+15 19	12.0*d*
U Serpentis	2.5	+10 12	10.4*d*	RU Aquilae	8.0	+12 42	<13.8
RU Herculis	6.0	+25 20	13.0*d*	W Capric.	8.6	−22 17	11.0 *i*
U Herculis	21.4	+19 7	11.0*d*	Z Aquilae	9.8	− 6 27	11.4 *i*
SS Herculis	28.0	+ 7 3	11.0 *i*	RS Cygni	9.8	+38 28	8.0 *i*
W Herculis	31.7	+37 32	9.5 *i*	R Delphini	10.1	+ 8 47	11.8*d*
R Draconis	32.4	+66 58	12.0*d*	RT Capricorni	11.3	−21 38	7.0 *i*
S Herculis	47.4	+15 7	9.7 *i*	SX Cygni	11.6	+30 46	13.6*d*
RV Herculis	56.8	+31 22	12.0*d*	WX Cygni	14.8	+37 8	11.0 *i*
RT Herculis	17 6.8	+27 11	14 *d*	U Cygni	16.5	+47 35	9.2 *i*
Z Ophiuchi	14.6	+ 1 37	8.0	RU Capric.	26.7	−22 2	13.2*d*
RU Ophiuchi	28.1	+ 9 30	12.5	Z Delphini	28.1	+17 7	<13.5
RS Herculis	17.5	+23 1	10.6*d*	ST Cygni	29.9	+54 38	10.9*d*
T Draconis	54.8	+58 14	10.0	Y Delphini	36.9	+11 31	9.3 *i*
RY Herculis	55.4	+19 29	14.0*d*	S Delphini	38.5	+16 44	8.3 *i*
V Draconis	56.3	+54 53	14.0*d*	V Cygni	38.1	+47 47	11.2*d*
T Herculis	18 5.3	+31 0	10.0 *i*	Y Aquarii	39.2	− 5 12	10.0 *i*
W Draconis	5.4	+65 56	14.0*d*	U Capricorni	42.6	−15 9	13.8*d*
X Draconis	6.8	+66 8	10.5 *i*	T Delphini	40.7	+16 2	14.0*d*
RY Ophiuchi	11.6	+ 3 40	9.0 *i*	V Aquarii	41.8	+ 2 4	8.6
W Lyrae	11.5	+36 38	12.4*d*	W Aquarii	41.2	− 4 27	11.8*d*
SV Herculis	22.3	+24 58	12.0 *i*	V Delphini	43.2	+18 58	<14
T Serpentis	23.9	+ 6 14	11.0 *i*	T Aquarii	44.7	− 5 31	11.0 *i*
T Serpentis	23.9	+ 6 14	11.0 *i*	RZ Cygni	48.5	+46 59	12.8*d*
RZ Herculis	32.7	+25 58	11.7*d*	X Delphini	50.3	+17 16	13.2*d*
X Ophiuchi	33.6	+ 8 44	9.0*d*	UX Cygni	50.9	+30 2	9.6 *i*
RY Lyrae	41.2	+34 34	13.7	R Vulpeculae	59.9	+23 26	12.2*d*
RW Lyrae	42.1	+43 32	11.6*d*	TW Cygni	21 1.8	+29 0	<14
Z Lyrae	56.0	+34 49	9.7 *i*	X Capric.	2.8	−21 45	13.0*d*
RX Lyrae	50.4	+32 42	<13.5	V Capric.	1.8	−24 19	12.8*d*
RT Lyrae	57.8	+37 22	<14	X Cephei	3.6	+82 40	<13.8
R Aquilae	19 1.6	+ 8 5	6.0 *i*	RS Aquarii	5.8	− 4 27	9.8 *i*
V Lyrae	5.2	+29 30	14.0	Z Capricorni	5.0	−16 35	10.8*d*
RX Sagittarii	8.7	−18 59	13.2*d*	R Equulei	8.4	+12 23	12.0 *i*
RW Sagittarii	8.1	−19 2	10.6*d*	T Cephei	8.2	+68 5	9.0*d*
S Lyrae	9.1	+25 50	10.7 *i*	RR Aquarii	9.8	− 3 19	11.0*d*
RS Lyrae	9.3	+33 15	<13.8	X Pegasi	16.3	+14 2	10.4 *i*
RU Lyrae	9.1	+41 8	10.0 *i*	T Capricorni	16.5	−15 35	13.4
U Draconis	9.9	+67 7	12.0 *i*	Y Capricorni	28.9	−14 25	<14.8
W Aquilae	10.0	− 7 13	13.4	S Cephei	36.5	+78 10	8.8 *i*
T Sagittarii	10.5	−17 9	12.0*d*	RU Cygni	37.3	+53 52	8.8
R Sagittarii	10.8	−19 29	7.3	RR Pegasi	40.0	+24 33	9.6*d*
S Sagittarii	13.6	−19 12	11.8*d*	V Pegasi	56.0	+ 5 38	9.6 *i*
Z Sagittarii	13.8	−21 7	11.0 *i*	U Aquarii	57.9	−17 6	12.6*d*
TZ Cygni	13.4	+50 0	11.0	RT Pegasi	59.8	+34 38	12.6*d*
U Lyrae	16.6	+37 42	9.0 *i*	T Pegasi	22 4.0	+12 3	12.0*d*
T Sagittae	17.2	+17 28	9.2*d*	Y Pegasi	6.8	+13 52	<13.6
TY Cygni	29.8	+28 6	11.6	RS Pegasi	7.4	+14 4	10.6 *i*
R Cygni	34.1	+49 58	12.0	X Aquarii	13.2	−21 24	13.6*d*
RT Aquilae	33.3	+11 30	13.0*d*	RT Aquarii	17.7	−22 34	12.8*d*
RV Aquilae	35.9	+ 9 42	12.0 *i*	RV Pegasi	21.0	+29 58	11.5*d*
RT Cygni	40.8	+48 32	12.8	S Lacertae	24.6	+39 48	8.0 *i*
TU Cygni	43.3	+48 49	14.0*d*	R Lacertae	38.8	+41 51	11.0*d*
X Aquilae	46.5	+ 4 13	9.5 *i*	S Aquarii	51.8	−20 53	13.2*d*
χ Cygni	46.7	+32 40	13.4*d*	RW Pegasi	59.2	+14 46	19.6*d*
RR Aquilae	52.4	− 2 11	13.0*d*	R Pegasi	23 1.6	+10 0	9.4*d*
RS Aquilae	53.7	− 8 9	12.0 *i*	V Cassiop.	7.4	+59 8	9.4*d*
Z Cygni	58.6	+49 46	13.2 *i*	W Pegasi	14.8	+25 44	8.8 *i*
S Cygni	20 3.4	+57 42	<14	S Pegasi	15.5	+ 8 22	12.0 *i*
SY Aquilae	2.3	+12 39	14.0*d*	Z Androm.	28.8	+48 16	11.0
R Capricorni	5.7	−14 34	12.0 *i*	— Androm.	33.8	+35 13	12.0

Approximate Magnitudes of Variable Stars on Nov. 1, 1907—Con.

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.	Name.	R.A. 1900. h	m	Decl. 1900. °	′	Magn.
R Aquarii	23	38.6	−15	50	10.6*d*	R Cassiop.	23	53.3	+50	50	8.5*d*
Z Cassiop.		39.7	+56	2	<14	Z Pegasi		55.0	+25	21	12.5 *i*
RR Cassiop.		50.7	+53	8	12.5*d*	W Ceti		57.0	−15	14	6.6 i
Z Aquarii		47.1	−16	25	8.8*d*	Y Cassiop.		58.2	+55	7	<13.5
V Ceti		52.8	− 9	31	14.0						

The letter *i* denotes that the light is increasing, the letter *d* that the light is decreasing, the sign <, that the variable is fainter than the appended magnitude.

The magnitudes given above have been compiled by Mr. Leon Campbell of the Harvard College Observatory, from observations made at the Leander McCormick, Vassar, Whitin and Harvard Observatories.

Maxima of Variable Stars of Short Period not of the Algol Type.

Unless otherwise indicated the times of maxima only are given; and the times of minima may be found by subtracting the interval printed in parentheses under the names of the stars.

RW Cassiop.

d	h
(−5	19)
Jan. 9	12
24	7

RX Aurigæ

d	h
(−4	0)
Jan. 2	12
14	3
25	18

Y Aurigæ

d	h
(−0	18)
Jan. 7	7
11	3
14	24
18	21
22	17
26	14
30	11

T Monoc.

d	h
(−7	23)
Jan. 12	9
Feb. 8	10

W Geminorum

d	h
(−2	22)
Jan. 3	17
11	15
19	13
27	11

ζ Geminorum

d	h
(−5	0)
Jan. 10	8
20	12
30	16

2.1907 Camel.

d	h
(−9	12)
Jan. 13	1
Feb. 4	8

RR Geminorum Period 9.5h

d	h
(−0	2)
Jan. 3	14
3	18
4	23
6	3

RR Geminorum

d	h
Jan. 7	8
8	13
9	17
10	22
12	2
13	7
14	11
15	16
16	21
18	2
19	6
20	11
21	15
22	20
24	1
25	5
26	10
27	14
28	19
30	0
31	4

V Carinæ

d	h
(−2	4)
Jan. 4	20
11	13
18	6
24	22
31	15

T Velorum

d	h
(−1	10)
Jan. 4	11
9	3
13	18
18	9
23	1
27	16

W Carinæ

d	h
(−1	0)
Jan 4	19
9	3
13	12
17	21
22	6

W Carinæ

d	h
Jan. 26	15
31	0

S Muscæ

d	h
(−3	11)
Jan. 4	14
14	6
23	22

T Crucis

d	h
(−2	2)
Jan. 2	9
9	2
15	20
22	13
29	7

R Crucis

d	h
(−1	10)
Jan. 4	15
10	11
16	7
22	3
27	23

S Crucis

d	h
(−1	12)
Jan. 3	1
7	17
12	10
17	2
21	19
26	12
31	4

W Virginis

d	h
(−8	5)
Jan. 17	16
Feb. 3	22

V Centauri

d	h
(−1	11)
Jan. 1	19
7	7
12	19
18	7
23	19
29	7

R Triang. Austr.

d	h
(−1	0)
Jan. 2	8
5	18
9	3
12	12
15	22
19	7
22	16
26	2
29	11

S Triang. Austr.

d	h
(−2	2)
Jan. 3	16
10	00
16	8
22	16
28	23

S Normæ

d	h
(−4	10)
Jan. 4	11
14	5
23	23

87.1906 Draco. Period = 10.6h

d	h
(−0	3)
Jan. 2	6
3	4
4	1
4	22
5	19
6	17
7	14
8	11
9	9
10	6
11	3
12	0
12	22
13	19
14	16
15	13
16	11
17	8

87.1906 Draco.

d	h
Jan. 18	5
19	2
19	23
20	21
21	18
22	15
23	13
24	10
25	7
26	4
27	2
28	23
28	20
29	17
30	15
30	12

RV Scorpii

d	h
(−1	10)
Jan. 7	0
13	2
19	3
25	5
31	6

RV Ophiuchi minimum.

d	h
Jan. 2	5
5	21
9	14
13	6
16	23
20	15
24	8
28	0
30	17

X Sagittæ

d	h
(−2	22)
2	20
9	21
16	21
23	21
39	22

Maxima of Variable Stars of Short Period not of the Algol Type.

Continued.

Y Ophiuchi			κ Pavonis			V Lacertæ			23.1907 Lacertæ			RS Cassiop.		
	d	h		d	h		d	h		d	h		d	h
	(−6	5)		(−1	7)		26	11		(−1	10)		(−1	19)
Jan.	15	13	Jan.	6	20		31	10	Jan.	2	19	Jan.	2	7
Feb.	1	16		15	22					7	3		8	14
				25	0		88.1906 Lacertæ			11	10		14	21
W Sagittarii			V Lacertae							15	18		21	4
	(−3	0)		(−0	17)		Minimum			20	1		27	11
Jan.	6	12	Jan.	1	13	Jan.	4	22		24	9	RY Cassiop.		
	14	3		6	12		10	9		28	17		(−7	10)
	21	17		11	12		15	19				Jan.	8	10
	29	7		16	12		21	6					20	14
				21	11		26	16						

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time beginning with noon. To reduce to Central Standard time subtract 6 hours, or for Eastern time subtract 5 hours.]

U Cephei			RZ Cassiop.			RT Persei			RW Tauri			24.1907 Monoc.		
	d	h		d	h		d	h		d	h		d	h
Jan.	3	2	Jan.	15	12	Jan.	12	9	Jan.	24	10			
	5	14		16	17		13	6		27	4	Jan.	6	15
	8	2		17	22		14	2		29	23		8	12
	10	14		19	2		14	22	RV Persei				10	10
	13	2		20	7		15	19	Jan.	1	18		12	8
	15	13		21	12		16	15		3	17		14	6
	18	1		22	16		17	11		5	17		18	1
	20	13		23	21		18	8		7	16		19	23
	23	1		25	2		19	4		9	15		21	21
	25	13		26	6		20	1		11	15		23	19
	28	1		27	11		20	21		13	14		25	16
	30	12		28	16		21	17		15	13		27	14
Z Persei				29	20		22	14		17	13		29	12
Jan.	3	13		31	1		23	10		19	12		31	10
	6	14	RX Cephei				24	7		21	12	RU Monoc.		
	9	16	Jan.	22	14		25	3		23	11	Jan.	1	13
	12	17	Algol				25	23		25	10		2	10
	15	18	Jan.	2	7		26	20		27	10		3	8
	18	20		5	4		27	16		29	9		4	5
	21	21		8	1		28	12		31	8		5	3
	24	22		10	22		29	9	RW Persei				6	0
	28	0		13	19		30	5	Jan.	4	19		6	22
	31	1		16	15		31	2		18	0		7	19
120.1906 Persei				19	12		31	22		31	5		8	17
Jan.	1	2		22	9	λ Tauri			RS Cephei				9	14
	7	23		25	6	Jan.	4	4	Jan.	7	19		10	12
	14	20		28	2		8	3		20	5		11	9
	21	16		30	23		12	2	RW Geminorum				12	7
	28	13	RT Persei				16	0	Jan.	3	12		13	4
RZ Cassiop.			Jan.	1	8		19	23		6	8		14	2
Jan.	1	4		2	5		23	22		9	5		14	23
	2	9		3	1		27	21		12	2		15	21
	3	13		3	21		31	20		14	23		16	18
	4	18		4	18	RW Tauri				17	19		17	15
	5	23		5	14	Jan.	2	6		20	16		18	13
	7	4		6	10		5	0		23	13		19	11
	8	8		7	7		7	19		26	10		20	8
	9	13		8	3		10	13		29	6		21	6
	10	18		9	0		13	8	24.1907 Monoc.				22	3
	11	22		9	20		16	2	Jan.	2	19		23	1
	13	3		10	16		18	21		4	17		23	22
	14	8		11	13		21	15					24	20
													25	17

Minima of Variable Stars of the Algol Type.—Continued.

RU Monoc.

	d	h
Jan.	26	15
	27	12
	28	10
	29	7
	30	5
	31	2

R Canis Maj.

Jan.	1	9
	2	12
	3	15
	4	18
	5	22
	7	1
	9	8
	10	11
	11	14
	12	17
	13	21
	15	0
	16	3
	17	6
	18	10
	19	13
	20	16
	21	19
	22	23
	24	3
	25	5
	26	8
	27	12
	28	15
	29	18
	30	22

Y Camelopardi

Jan.	1	16
	5	0
	8	7
	11	14
	14	22
	18	5
	21	12
	24	20
	28	3
	31	10

RR Puppis

Jan.	6	10
	12	20
	19	7
	25	17

V Puppis

Jan.	2	6
	3	17
	5	4
	6	15
	8	2
	9	13
	11	0
	12	10
	13	21
	15	8
	16	19
	18	6
	19	17
	21	4

V Puppis

Jan.	22	15
	24	2

V Puppis

Jan.	25	13
	27	0
	28	10
	29	21
	31	8

X Carinæ

Jan.	1	2
	2	4
	3	6
	4	8
	5	10
	6	11
	7	13
	8	15
	9	17
	10	19
	11	21
	12	23
	14	1
	15	3
	16	5
	17	7
	18	9
	19	11
	20	13
	21	15
	22	17
	23	19
	24	21
	25	23
	27	1
	28	3
	29	5
	30	7
	31	9

S Cancri

Jan.	8	14
	18	1
	27	13

S Velorum

Jan.	5	10
	11	8
	17	7
	23	5
	29	3

RR Velorum

Jan.	1	4
	3	1
	4	21
	6	17
	8	14
	10	10
	12	7
	14	3
	16	0
	17	20
	19	17
	21	13
	23	10
	25	6
	27	3

RR Velorum

Jan.	28	23
	30	20

SS Carinae

Jan.	2	0
	5	8
	8	15
	11	22
	15	5
	18	12
	21	20
	25	3
	28	10
	31	17

Z Draconis

Jan.	1	2
	2	10
	3	19
	5	0
	6	12
	7	21
	9	5
	10	14
	11	23
	13	7
	14	16
	16	0
	17	9
	18	17
	20	2
	21	10
	22	19
	24	4
	25	12
	26	21
	28	5
	29	14
	30	22

141.1906 Centauri

Jan.	1	19
	2	18
	3	16
	4	15
	5	13
	6	12
	7	10
	8	9
	9	7
	10	6
	11	4
	12	3
	13	1
	14	0
	14	22
	15	21
	16	19
	17	18
	18	16
	19	15
	20	13
	21	12
	22	10
	23	9
	24	7

141.1906 Centauri

Jan.	25	6
	26	4
	27	3
	28	1
	29	0
	29	22
	30	21
	31	19

149.1906 Centauri

Jan.	1	3
	3	15
	6	2
	8	14
	11	1
	13	13
	16	0
	18	12
	20	23
	23	11
	25	22
	28	10
	30	21

δ Libræ

Jan.	2	23
	5	7
	7	15
	9	23
	12	7
	14	14
	16	22
	19	6
	21	14
	23	22
	26	6
	28	14
	30	21

U Coronæ

Jan.	1	11
	4	22
	8	8
	11	19
	15	6
	18	16
	22	3
	25	14
	29	1

R Aræ

Jan.	4	21
	9	7
	13	17
	18	4
	22	14
	27	0

U Ophiuchi

Jan.	1	1
	1	21
	2	17
	3	13
	4	10
	5	6
	6	2
	6	22

U Ophiuchi

Jan.	7	18
	8	14
	9	10
	10	7
	11	3
	11	23
	12	18
	13	15
	14	11
	15	7
	16	3
	17	0
	17	20
	18	16
	19	12
	29	8
	21	4
	22	0
	22	20
	23	17
	24	13
	25	9
	26	5
	27	1
	27	21
	28	17
	29	14
	30	10
	31	6

Z Herculis

Jan.	2	10
	4	13
	6	10
	8	13
	10	10
	12	13
	14	10
	16	12
	18	9
	20	12
	22	9
	24	12
	26	9
	28	12
	30	9

121.1906 Draconis

Jan.	2	17
	4	14
	6	12
	8	9
	10	7
	12	4
	14	2
	15	23
	17	21
	19	18
	21	15
	23	13
	25	10
	27	8
	29	5
	31	3

New Variable Star 137.1907 Ursæ Majoris.—In *A. N.* 4202 Professor W. Ceraski of the Moscow Observatory announces a new variable in Ursa Major. Its position is

1855.0	$\alpha = 11^h\ 34^m\ 01^s$	$\delta = +39°\ 17'.2$
1900.0	$11^h\ 36^m\ 25^s$	$+39°\ 02'.3$

The examination of four photographs indicates the following degrees of brightness:

1906	May 13	< 11 mag. (invisible)
1907	Mar. 18	9.0
	Apr. 7	9.1
	Apr. 15	9.6

Three New Variables 138-140.1907.—These are announced in *A. N.* 4207 by Professor W. Ceraski. Their positions are as follows:

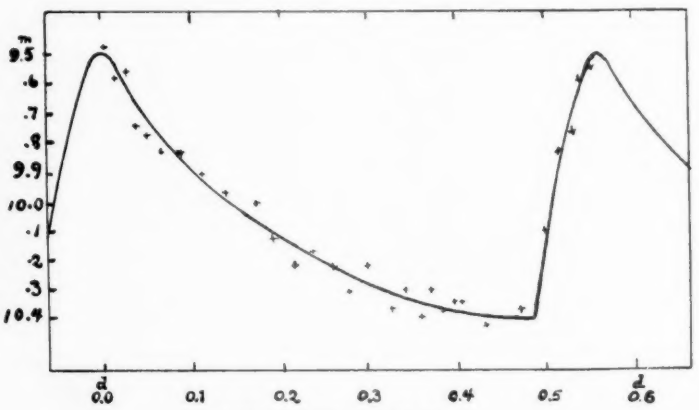
		α 1855	δ 1855	α 1900.0	δ 1900.0
		h m s	° ′	h m s	°
138.1907	Can. Ven	13 42 34	+42 06.2	13 44 29	+41 52.7
139.1907	Urs. Maj.	13 27 34	+54 44.5	13 29 27	+54 30.6
140.1907	Can. Ven.	14 00 21	+38 31.3	14 02 15	+38 18.3

The first of these upon five photographs, two taken in May 1906 and three in April and May 1907, indicate a variation between 11.3 and 11.9 magnitude. The period is unknown except that it is less than a year.

The second varies apparently between the magnitudes 9.2 and 9.9 and the period is short. The third varies between 8.8 and 9.5 magnitude and the period is possibly short.

The Light Curve of UY Cygni.—In *A. N.* 4203 Mr. M. Luizet of Lyons, France, gives a chart showing the place of this variable and a diagram showing the curve of light variation. His observations are numerous extending from May 25, 1906 to January 12, 1907. The observations are well represented by the elements given by Mr. Stanley A. Williams:

Max. = 2415346.3933 (Gr. M. T.) + 0.5607103 E.



LIGHT CURVE OF UY CYGNI

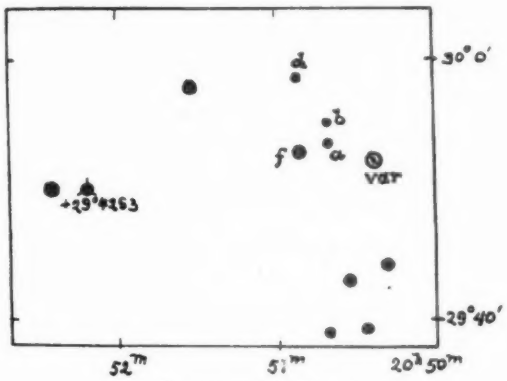


CHART OF UY CYGNI

The star is of the δ Cephei type falling slowly from magnitude 9.5 to 10.4 in about 12 hours and rising very rapidly, regaining its maximum brightness in about 2 hours.

Maxima of Variable Stars.—In *A. N.* 4207 Mr. S. Enebo of Dombaas, Norway, gives the following elements of long period variables:

	Maximum. Julian Day.	Period
Z Ursæ Maj.	2417552	+ 102ᵈE
Y Ursæ Maj.	2417480	+ 208 E
RS Ursæ Maj.	2417109	+ 310 E
RV Cassiop.	2416785	+ 512 E
W Draconis	2417528	+ 245 E
X Draconis	2417668	+ 503 E
RS Aurigæ	2417637	+ 171 E
X Cancri	2416598	+ 362 E

He also gives elements of the Algol Star RV Persei depending upon two well determined minima 2417668.46111 and 2417826.34453 (middle European time):

Minimum = 2417668.46111 (M. E. T.) + 1.973543 E.

These agree well with those given in our October number.

The Period of RZ Ophiuchi.—In *A. N.* Mr. K. Graff reports that this star was at minimum brightness on the nights of September 22, 23, 24, 25, 26, 28, 29 and 30, 1907, and that on October 2 it had regained full maximum brightness. The first signs of light change began on the night of September 20 so that most of the descent of the light curve must have occurred during September 21, and the ascent during October 1. On both of the latter mentioned dates the sky was cloudy. Mr. Graff thinks that the long period of 261.8 days is established and that the light change occupies about 12 days. If this be as is supposed a variable of the Algol type, the eclipsing dark star must be enormous in size compared with the bright star.

The Light Curve of RR Geminorum.—In *A. N.* 4207 Mr. M. Luizet gives a long series of observations of this variable, from which he deduces the accompanying light curve. This shows the star to be of the

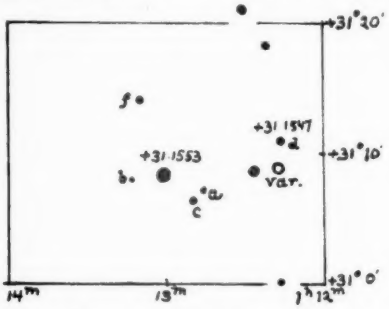
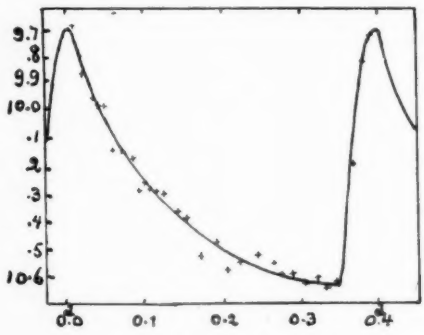


CHART of RR GEMINORUM

δ Cephei type, having a sharp maximum, descending rapidly at first and then more slowly to minimum, then rising rapidly to maximum. The diminution of light occupies $8^h\ 20^m$ while the increase requires only $1^h\ 12^m$.



LIGHT CURVE OF RR GEMINORUM

The little chart shows the comparison stars used by Mr. Luizet. The observations are well satisfied by the elements of Mr. Graff.

Max. = 2416223.286 Gr. M. T. + 0.3972927 E.

GENERAL NOTES.

Mr. S. J. Corrigan's Article, leader for this issue introduces a very important theme for the consideration of physicists and astronomers. The author has been at work on a group of kindred physical problems for more than twelve years and the results obtained are curiously and surprisingly related. They are attracting the attention of leading physicists in Europe. We have given large space to introductory remarks, this time, so as to clear the way, for the data of his new theory in following numbers.

Transit of Mercury. The conditions of observation were very favorable at Harvard, until just at the time of the contacts, when the wind rose. At the time of fourth contact, the Sun's limb showed wavy motions. The writer used a 5-inch refractor fitted with a polarizing solar eye-piece and a magnification of 70 diameters. Prior to the contacts a higher power could have been used to advantage had it been available. Towards the end of the observation improved definition was obtained by reducing the aperture to three inches. Various apertures were tried, and it was found that the planet could be well seen when a ½-inch diaphragm was placed over the objective. With a ¼-inch diaphragm the planet was invisible.

An attempt was made using different apertures and depth of obscuration to see the white point due to diffraction supposed to be visible within the disk of the planet, and the dark halo surrounding it. Once or twice the white spot was suspected with the 3-inch aperture, but little reliance can be placed on the observation. At the request of Professor Snyder an attempt was made to see the complete outline of the planet when half of the disk was projected on the chromosphere. The results were entirely negative. The third contact occurred at $1^h\ 48^m\ 09^s$, and the fourth at $1^h\ 50^m\ 37^s$ G. M. T. The former, which is the more reliable, is 51 seconds later than the time given in the American Ephemeris.

WILLIAM H. PICKERING.

November 14. 1907.

Transit of Mercury at Ladd Observatory. At the Ladd Observatory Providence, R. I., the times of third and fourth contact were observed with the 12-inch equatorial, power 180, polarizing helioscope. The times (in Greenwich Time) were 1h 48 min. 26 sec. and 1h 50 min. 48 sec. respectively. The times calculated by the formulae in the American Ephemeris were 1h 48 min. 18.5 sec. and 1h 50 min. 57.2 sec. The definition was fair, the sky clear. About five seconds before third contact a black ligament connected the planet's disk with the trembling edge of the Sun. Between third and fourth contacts an attempt was made to see the portion of the planet beyond the Sun's limb, the telescope moved back and forth as suggested by Professor Snyder. When the planet was about half off, a complete disk was suspected for an instant only, the part of the Sun's disk having an uncertain boundary, but this suspicion could not be confirmed. The Sun's edge was too wavy for the times of the contacts to be obtained within several seconds.

WINSLOW UPTON.

Ladd Observatory,
Providence, R. I.
Nov. 14, 1907.

The Transit of Mercury at Flower Observatory. The egress was observed with the 18-inch equatorial of the Flower Observatory, the times being recorded by the chronograph and also read from the sidereal chronometer as a check. The uncertainty of the clock error will not exceed 0.1 seconds. The definition was only moderately good and the pressure of the "Black drop" was troublesome so that it is difficult to estimate the probable uncertainty of the recorded times of the contacts, but I think that this can hardly exceed five or six seconds.

The recorded sidereal times were changed to local mean time are as follows:

Third contact, (Interior) $20^h\ 47^m\ 20.2^s$
Fourth contact, (Exterior) $20^h\ 49^m\ 33.3^s$

Adopting $5^h\ 1^m\ 6.6^s$ as the longitude, the resulting Greenwich Mean Times are,

$1^h\ 48^m\ 26.8^s$
$1^h\ 50^m\ 39.9^s$

The values of these quantities computed from the formulas of the American Ephemeris, page 442, are as follows.

$1^h\ 48^m\ 17.5^s$
$1^h\ 50^m\ 56.3^s$

The observed third contact is thus 9.3 seconds later than the computed time and the fourth is 16.4 seconds earlier.

The disk of Mercury appeared perfectly black; no trace ot a bright ring or other evidence of an atmosphere could be seen at any time during or just after the transit though these were carefuliy looked for.

ERIC DOOLITTLE.

The Flower Observatory,
University of Pennsylvania. Nov. 17, 1907.

Professor D. A. Morehouse of Drake University, Des Moines, observed the November meteors on the morning of November 14, between 3:30 A. M. and 6. Those assisting were in groups of twos and threes, and so arranged that about the whole sky was under watchful view at once. His charts have not yet come to hand. He says the Leonids were not many in number and they were generally small. There were, however, two or three very brilliant ones. The trail of one of these was about ninety degrees long extending through α Leonis and γ Virginis. We will be glad to see the charts.

Spectroscopic Binaries. The *Lick Observatory Bulletins* Nos. 122 and 123 contain the determinations of the orbits of five spectroscopic binary stars. Velocity curves are given which as usual show the extreme accuracy of the Lick measures.

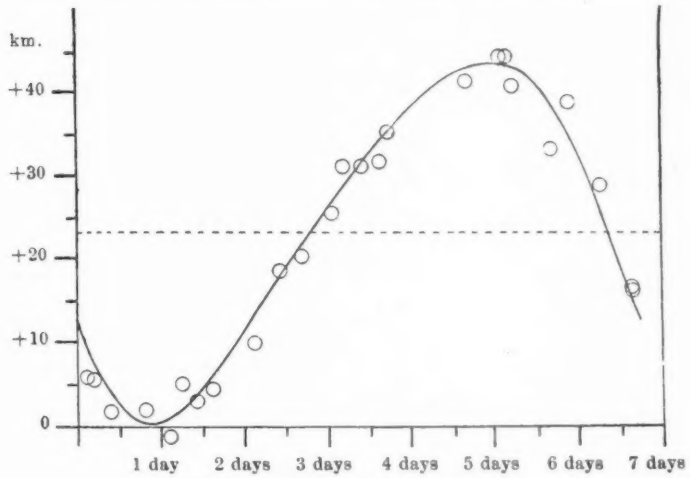
α *Carinæ*.—The binary character of this star was discovered by Professor W. H. Wright in the course of the work of the D. O. Mills Expedition to the Southern Hemisphere. It is of visual magnitude 3.5 and the exposure time used for the spectrograms was fifty to sixty minutes under average observing conditions. It contains in the part of the spectrum covered by the spectroscope of the Mills Reflector, only the following six lines:

λ 4267.316	C	λ 4437.718	He: generally rather faint.
4340.634	H	4471.646	He
4388.100	He	4481.400	Mg

The elements resulting from measures of twenty-five spectrograms are:

Period = 6.744 days	$\mu = 58°.380$
T = J. D. 241653381	$e = 0.18$
$\omega = 115°.84$	Velocity of system = + 23.3 km.
K = 21.5	$a \sin i$ = 1,960,000, km.

α *Pavonis*.—This was suspected of being a binary by Professor W. H. Wright in Chile from preliminary measures of the first four plates taken, and its binary character was independently discovered from the definition reductions

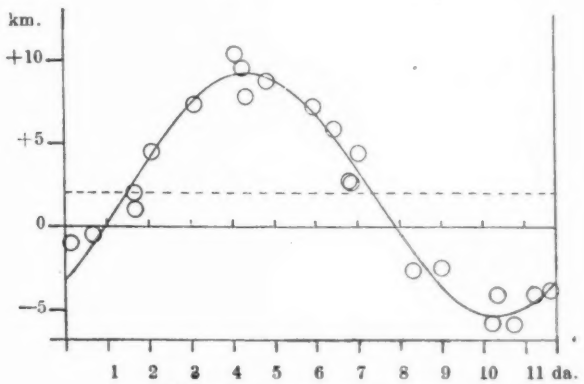


VELOCITY CURVE OF α CARINÆ

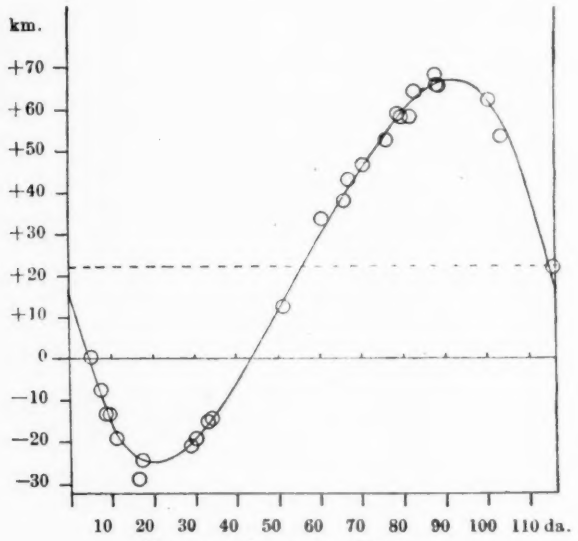
of the same plates by Dr. S. Albrecht at Mount Hamilton. The star is of the same type with α Carinae and κ Velorum though the lines are somewhat better than those stars. Its visual magnitude is 2.0. Under fair observing conditions satisfactory plates can be secured in twenty-two to twenty-six minutes. The elements derived from measures of twenty-two plates are:

Period = 11.753 days
$e = 0.01$ $\omega = 224.80$
K = 7.25 Velocity of system = + 2.0 km
T = J. D. 2416379.99 $a \sin i = 1{,}170{,}000$ km

The velocity curve and the separate observations are plotted in the accompanying diagram, the dotted line representing the velocity of the center of mass of the system.

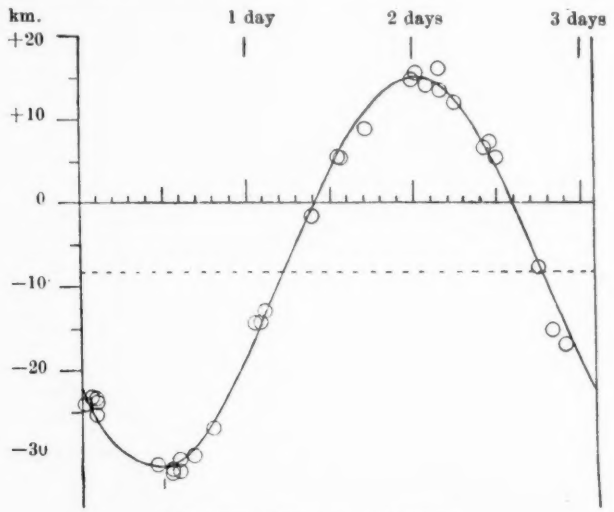


VELOCITY CURVE OF α PAVONIS



VELOCITY CURVE OF κ VELORUM

κ Velorum.—The binary nature of this star was discovered by Professor W. H. Wright on the Mills Expedition. The star is of the type *B* 3 *A* in the Harvard classification; its visual magnitude is 2.6. The elements derived from measures of twenty-seven plates are as follows:



VELOCITY CURVE OF θ DRACONIS

Period = 116.65
e = 0.19
K = 46.5
T = J. D. 2416459.00
ω = 96°.23
Velocity of system = + 21.9 km.
$a \sin i$ = 73,200,000 km.

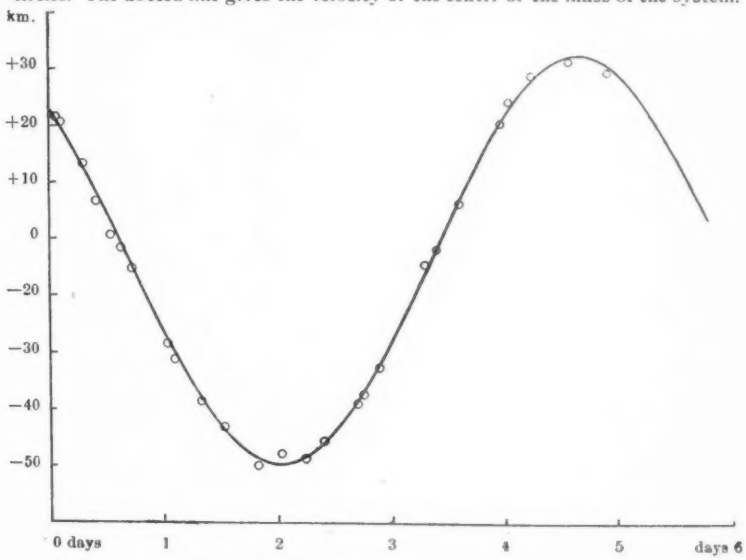
In this accompanying diagram the dotted line gives the velocity of the center of mass of the system, the total range being ninety-three kilometers. Future observations may change the period slightly, as it covers only about fourteen revolutions of the system.

θ Draconis. This binary was discovered by W. W. Campbell, Director of Lick Observatory. Its visual magnitude is 4.1 and its photographic 4.8. Its type in the Harvard classification is F and XIIIa, and by Potsdam, IIa. Its lines are not easy to measure because they are diffuse and of poor quality.

The following final elements depend on the weighted measures of thirty-two plates, and a set of preliminary elements, from which an ephemeris was computed and differential coefficients derived. These give the corrections needed for the final elements.

Period = 3.708 ± 0.000032 days
e = 0.0141 ± 0.0166
T = J. D. 2415368.962 ± 499
ω = 126°.112 ± 58°.6
K = 23.47 ± 0.324
Velocity of system = − 8.36 km. ± 0.30 km.
$a \sin i$ = 9.900,000 km.

The probable error of a plate is 0.87 km. This is represented in the diagram of the velocity curve and the observations by the radius of the small circles. The dotted line gives the velocity of the center of the mass of the system.



VELOCITY CURVE OF ω DRACONIS

ω Draconis. This spectroscopic binary was also discovered by Director Campbell of the Lick Observatory and announced by him in the Astrophysical Journal (X.179). It is an F type star, with rather broad fuzzy lines.

The orbit depends on twenty-six plates measured and reduced by Arthur B. Turner of Lick Observatory. In finding the final elements the same method was used as in the the case of θ Draconis.

They are as follows:

Velocity of system = − 13.68 ± 0.16 km.
T = 1906 July 23.493 ± 0.394 days
Julian Day 2417385.493
e = + 0.0107 ± 0.0060
ω = 333°.761 ± 26°.9
log μ = 0.0755725 ± 0.0000027
u = 68°.1860 ± 0°.0004
K = 36.26 ± 0.24
Period = 5.27968 ± 0.00003 days
$a \sin i$ = 2.632,300 km.

The final velocity curve is represented in the accompanying diagram, and the observed places given by the plates are shown by the small circles. The velocity of the center of the mass of the system is shown by the dotted line.

Elements of the Double Star β 612.—In *A. N* 4208 Mr. L. Semenow, a student of astronomy at Strassburg gives a determination of the elements of the orbit of this close double, of which the first measure was by Burnham in 1878. Of the two sets of elements given the second represents all the observations well except the first four.

	I	II	
	°	°	
Ω	89.75	90.62	
i	6.35	4.51	
ω	17.43	18.43	
e	0.24	0.26	
	"	"	
a	0.24	0.36	
Period	68.7	72.43	years
T	1881.25	1880.95	
Motion	direct.		

The predicted position angles and distances for the next two years are

	θ	P
	°	"
1907.5	258.69	0.432
1908.0	260.36	0.434
1908.5	261.96	0.436
1909.0	263.64	0.438

Computation of a Planet's Anomaly and Radius Vector. We have received an article that purports to be a new method for computing a planet's anomaly and its radius vector. One of the interesting points in the discussion is the way its author handles the Kepler problem. For lack of space we must defer the article until next issue.